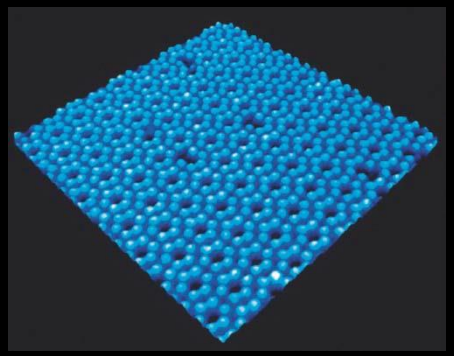
Earth Materials

Minerals & Rocks



Matter

An atom is the smallest unit of an element that possesses the properties of the element. It consists of a nucleus of protons and neutrons and a surrounding cloud of electrons. There are three states of matter: gas, liquid, and solid. Each state is distinguished by unique physical properties. Processes in Earth's dynamics mostly involve the changing of matter from one state to another.

Nature of Minerals

A mineral is a natural inorganic solid with a specific internal structure and a chemical composition that varies only within specific limits. All specimens of a given mineral, regardless of where, when, or how they were formed, have the same physical properties (including cleavage, crystal form, hardness, density, color, luster, and streak). Minerals also have restricted stability ranges.

Earth Materials

Minerals & Rocks

- Mineral adalah **benda padat homogen yang terbentuk dialam, inorganik dan mempunyai struktur kristal padat, dengan komposisi kimia tertentu dan mempunyai sifat fisik tertentu**
- Setiap mineral mempunyai susunan atom yang teratur membentuk kristal padat.
- *Native Elements* merupakan mineral yg tidak umum, tetapi beberapa diantaranya mempunyai nilai ekonomik yang tinggi seperti emas, tembaga, perak, diamond dan graphite.
- Mineral dapat mempunyai komposisi kimia yang bervariasi. Variasi ini terjadi akibat proses subtitusi atom dari satu elemen ke elemen lainnya. Subtitusi ini dapat terjadi apabila kesetimbangan elektrik terjadi dalam struktur atom, dan jika elemen yang mengsubtitusi mempunyai jari-2 atom yang hampir sama.
- Lebih dari 3500 mineral adalah silikat (gabungan Si, O dan elemen lainnya). Seperti Feromagnessian silikat mengandung Fe dan Mg. Group mineral lainnya adalah karbonat, sulfida, sulfat, dan halida.

Earth Materials

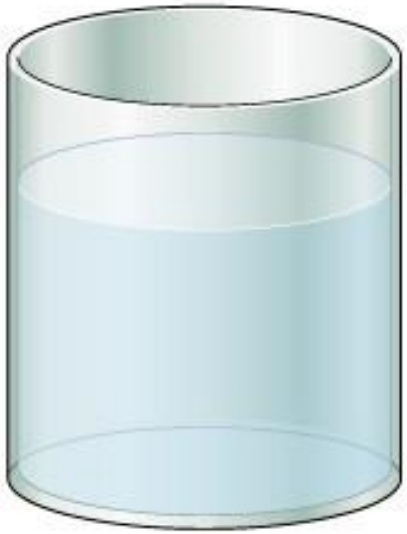
Atom & Element

- Setiap materi terdiri dari atom.
- Atom terdiri dari inti (*nucleus)* yang terdiri dari *proton* dan *neutron* serta *electron* yang mengelilinginya.
- Elemen didefinisikan berdasarkan jumlah *proton* didalam inti.
- Masa Atom (atomic mass) adalah jumlah proton dan neutron dalam inti.
- Elemen dengan bentuk yang sama tetapi mempunyai masa berbeda dinamakan isotop.
- Jumlah elektron yang mengelilingi inti sama dengan jumlah proton didalam inti.
- Atom saling bergabung dikarenakan gaya ikat (bonding).
- Atom dari elemen-2 yang berbeda saling terikat membentuk *compounds*.
- Pada umumnya mineral adalah *compound,* tetapi hanya sedikit yang mempunyai satu jenis elemen yang dikenal sebagai *native elements*.

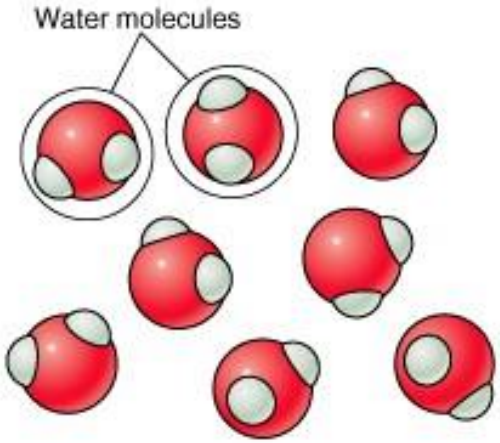
Geology ITB

Earth Materials

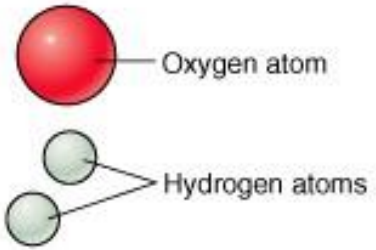
Minerals & Rocks



Matter – Water

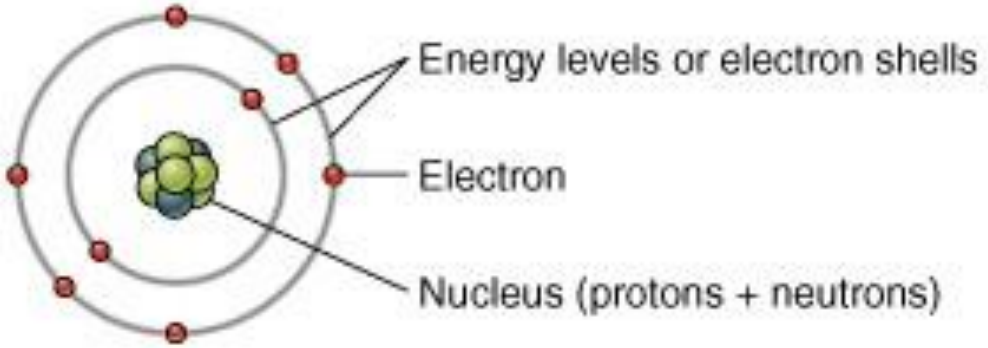


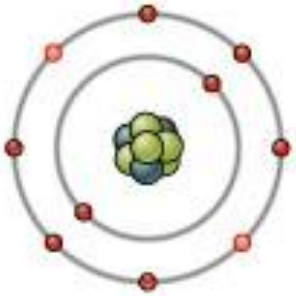
Molecules of water containing the chemical elements hydrogen and oxygen



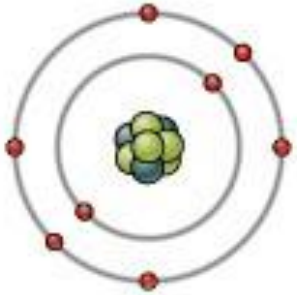
Elements made up of atoms

ATOM





Two electrons (●) have been added to completely fill the outer energy level. This means that the atom is now an ion with a –2 charge because it has 2 more electrons than protons.



ANION, KATION, MASA DAN NOMER ATOM

ISOTOPE: ATOM DGN JUMLAH NEUTRON BERBEDA

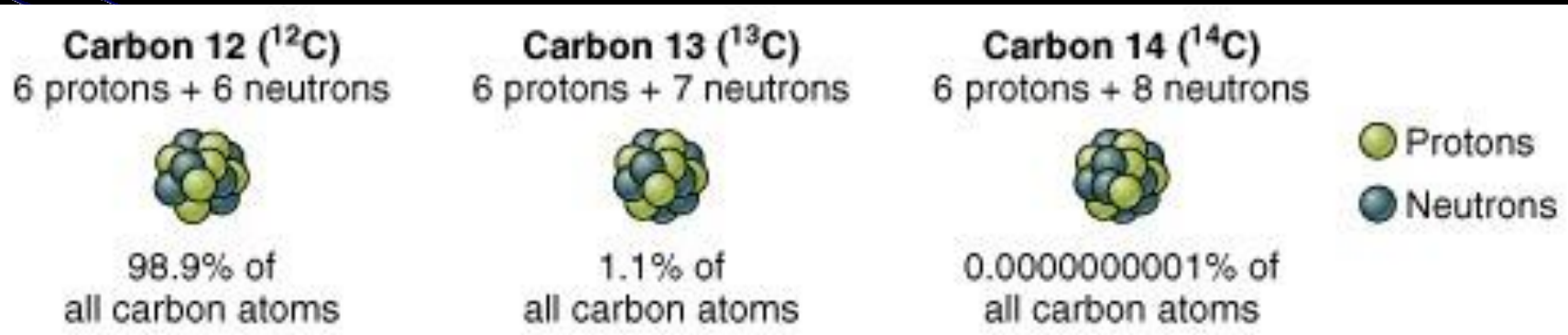
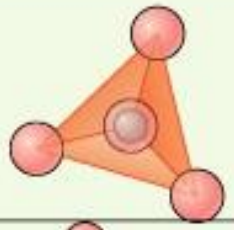
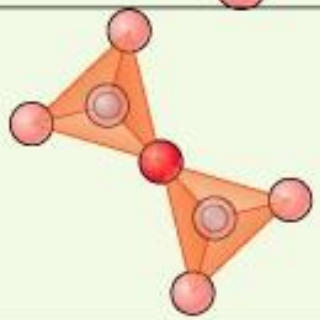
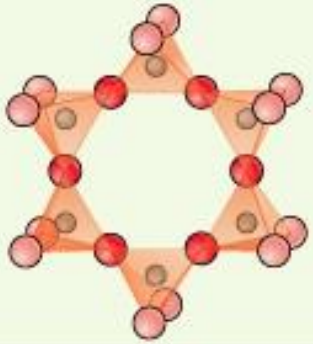


TABLE EM2.2-1

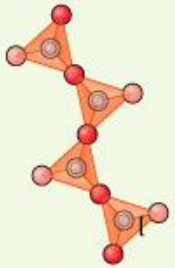
Group	Schematic Arrangement of Silica Tetrahedra	Unit Composition and silicon: oxygen ratio	Example mineral and formula
Nesosilicates Isolated tetrahedra bonded to positive ions. There is no sharing of oxygen ions between tetrahedra.		$[SiO_4]^{4-}$ 1:4	Olivine $(Mg,Fe)_2SiO_4$
Sorosilicates Two silica tetrahedra linked with one shared oxygen ion. Other positive ions bond to remaining oxygen ions at unshared tetrahedra corners.		$[Si_2O_7]^{6-}$ 2:7	Epidote $Ca_2(Fe,Al)Al_2O(SiO_4)(Si_2O_7)(OH)$
Cyclosilicates Three or more silica tetrahedra linked into closed rings. Each tetrahedron shares oxygen ions with two adjacent tetrahedra. Other positive ions bond to unshared oxygen ions.		$[Si_6O_{18}]^{12-}$ $Si_x:O_{3x}$	Beryl $Be_3Al_2Si_6O_{18}$

SILIKAT STRUKTUR-2

Inosilicates

Infinitely linked tetrahedra forming single or double chains.

In single chains two oxygen ions from each silca tetrahedra are shared.



$[SiO_3]^{2-}$
1:3

Pyroxene
$MgSiO_3$

Double chains are two single chains linked to each other where either 2-3 oxygen ions of each silica tetrahedron are shared.

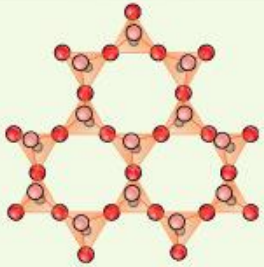
Other positive ions bond to unshared oxygen ions to link the chains together. The hydroxyl ion (OH^-), fits loosely in the openings between the two tetrahedral chains.

$Si_4O_{11}]^{6-}$
4:11

Amphibole
$(Ca,Na)_{2-3}(Mg,Fe,Al)_5$
$Si_8O_{22}(OH)_2$

Phyllosilicates

Also known as sheet silicates. The three oxygen ions at the base of the silca tetrahedra are all shared, producing infinitely flat sheet in two-dimensions. Other positive ions bond to unshared oxygen ions.

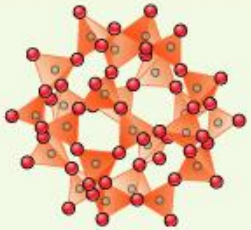


$[Si_2O_5]^{2-}$
2:5

Muscovite
$KAl_2(AlSi_3O_{10})(OH)_2$

Tectosilicates

Also known as the framework silicates. All four oxygen ions of the silica tetrahedra are shared to form a three-dimensional framework. Other positive ions bond to the structure to balance charges that result from Al^{3+} substitution for Si^{4+}.



SiO_2
1:2

Quartz
SiO_2

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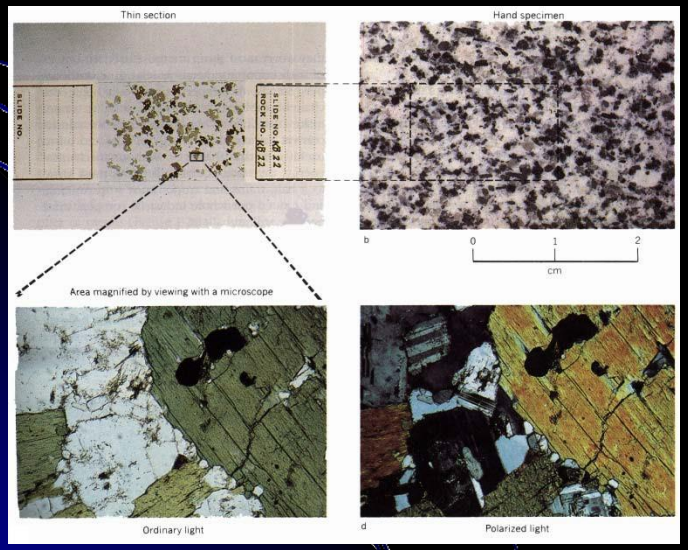
Earth Materials

Minerals & Rocks

Crystals & Minerals



Microscopic view

Mineral dan Batuan

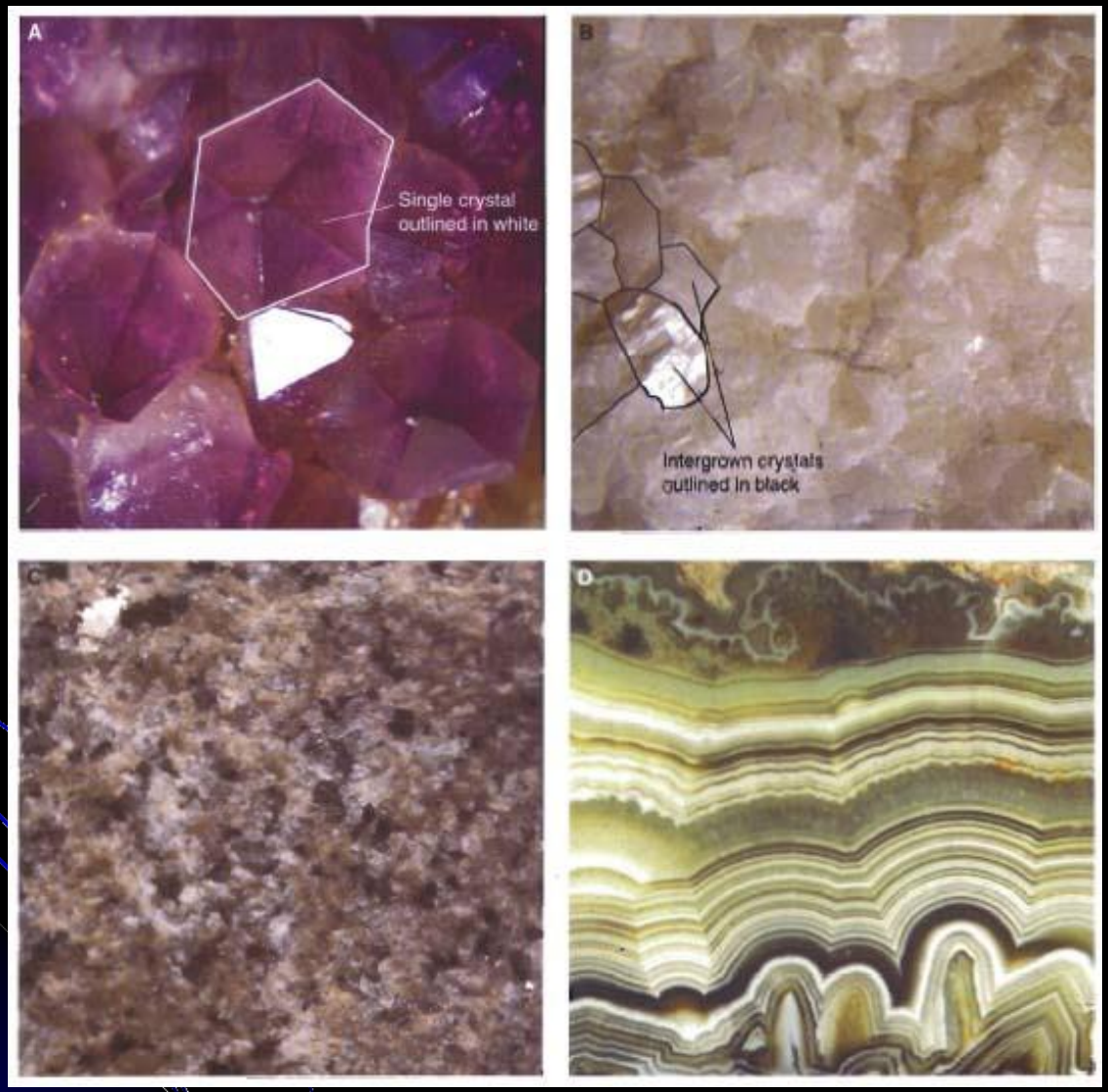
Mineral dan Batuan

- Komposisi dan struktur mineral membentuk sifat fisik seperti warna, kekerasan, *cleavage*, bentuk kristal dan *specific gravity*.
- Beberapa mineral termasuk sangat umum dijumpai pada batuan sehingga dikenal sebagai mineral pembentuk batuan (*rock-forming*). Kebanyakan dari jenis ini adalah silikat, tetapi beberapa dari group karbonat juga sangat penting terutama dalam batuan sedimen.
- Sumberdaya mineral adalah tempat terkonsentrasinya mineral ekonomis yang penting. Cadangan adalah konsentrasi dari sumberdaya mineral yang mempunyai nilai ekonomis.
- Catatan: Persentasi volume dari 8 elemen utama: Oxigen (93.8%), Potassium (1.8%), Sodium (1.3%), Calcium (1.0%), Silikon (0.9%), Aluminum (0.5%), Iron (0.4%), Magnesium (0.3%)

Geology ITB

Mineral dan Batuan

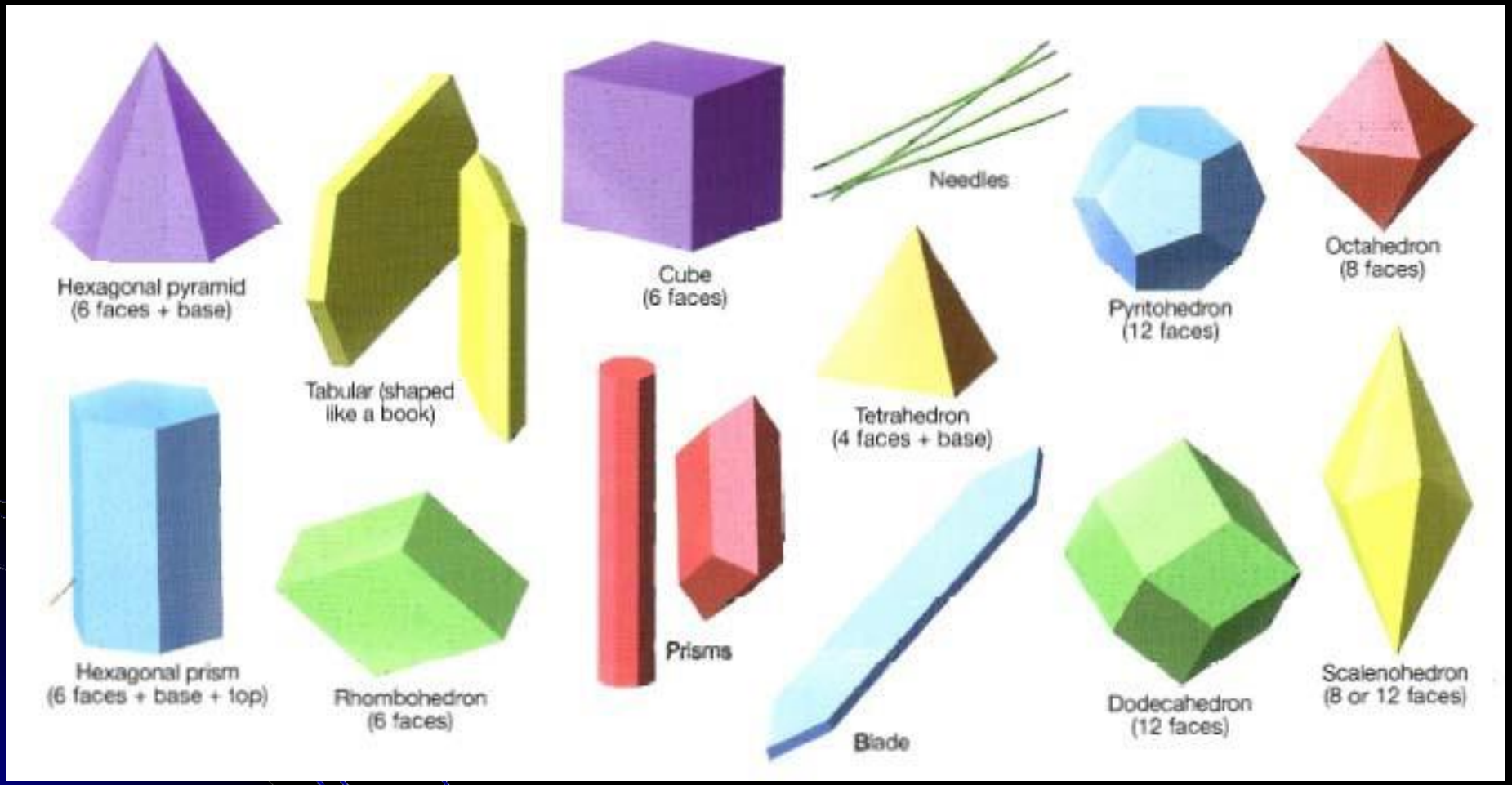
Kristal & Mineral



Crystals, Minerals & Rocks

Mineral dan Batuan

Kristal & Mineral

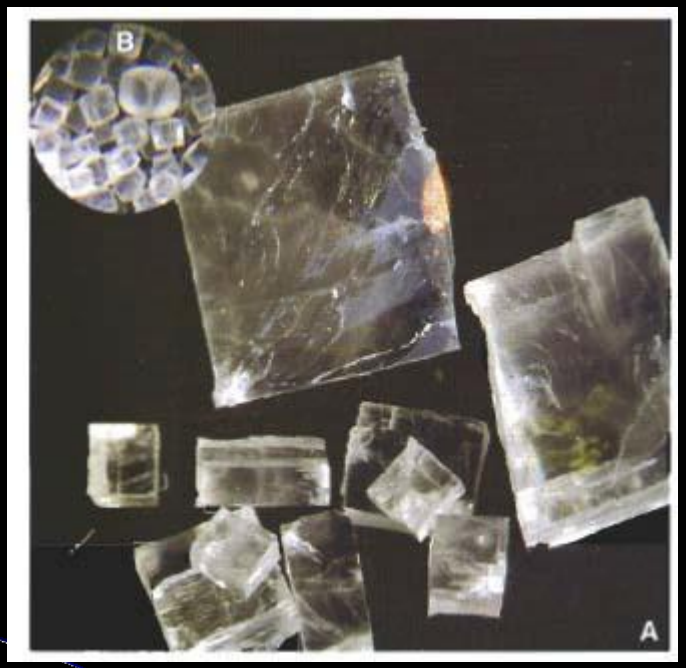


Crystal Forms

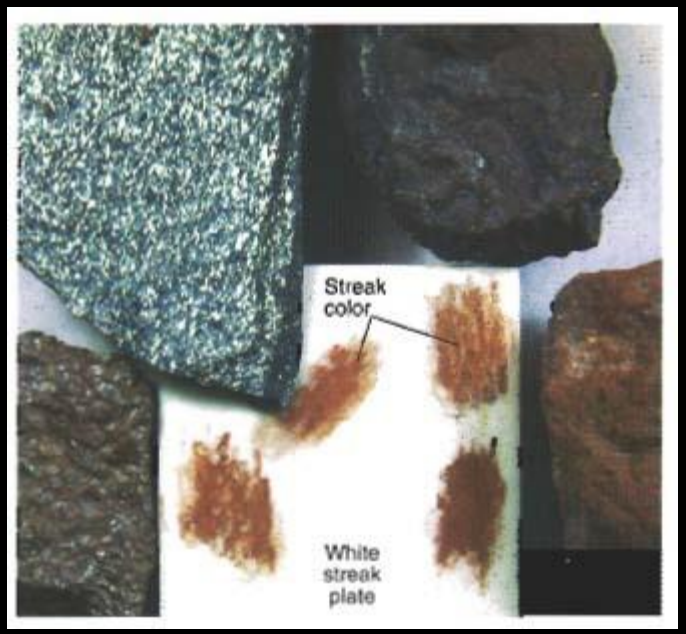
Geology ITB

Mineral dan Batuan

Kristal & Mineral



HALITE



HEMATITE

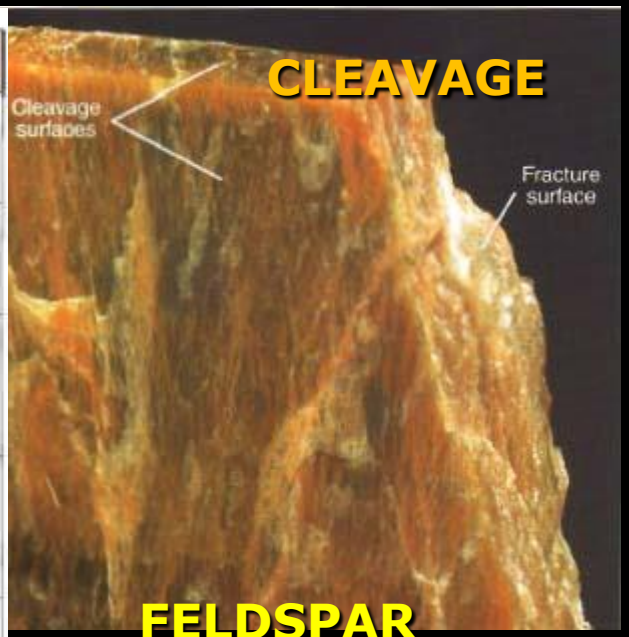
- Crystal Form
- Color
- Lustre
- Streak
- Cleavage
- Hardness

Physical Properties

Mineral dan Batuan

Kristal & Mineral

Number of Cleavage Directions	Shapes that Crystal Breaks Into	Sketch	Illustration of Cleavage Directions
0 No cleavage, only fracture	Irregular masses with no flat surfaces		None
1	Basal cleavage "Books" that split apart along flat sheets		
2 at 90°	Elongated form with rectangular cross sections (prisms) and parts of such forms		
2 not at 90°	Elongated form with parallelogram cross sections (prisms) and parts of such forms		
3 at 90°	Cubic cleavage Shapes made of cubes and parts of cubes		
3 not at 90°	Rhombohedral cleavage Shapes made of rhombohedrons and parts of rhombohedrons		
4	Octahedral cleavage Shapes made of octahedrons and parts of octahedrons		
6	Shapes made of dodecahedrons and parts of dodecahedrons		



FELDSPAR

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Mineral dan Batuan

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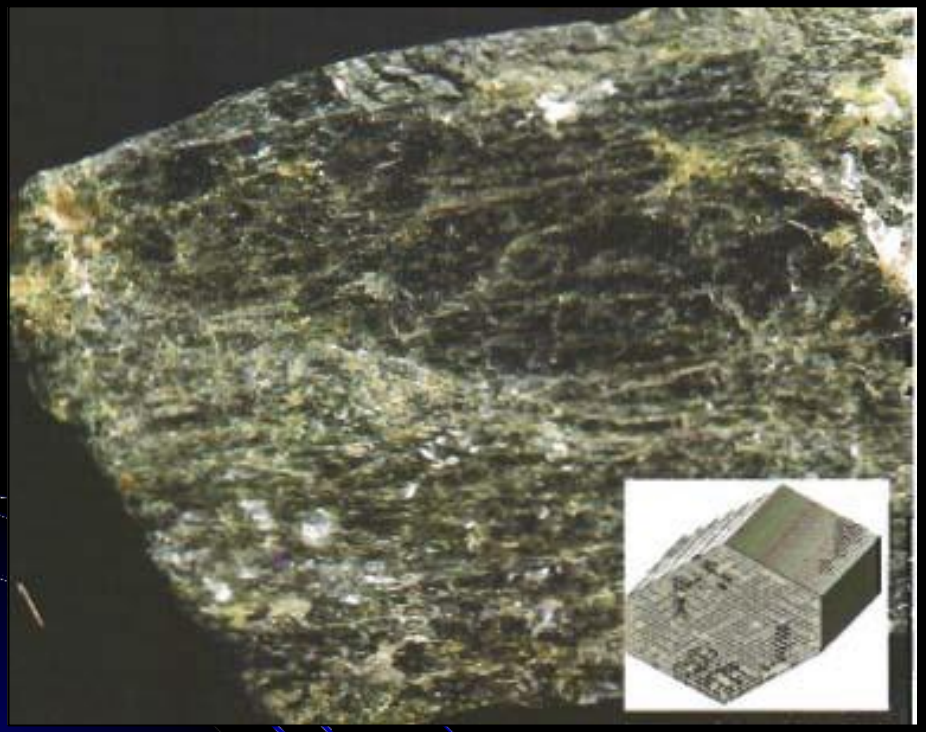
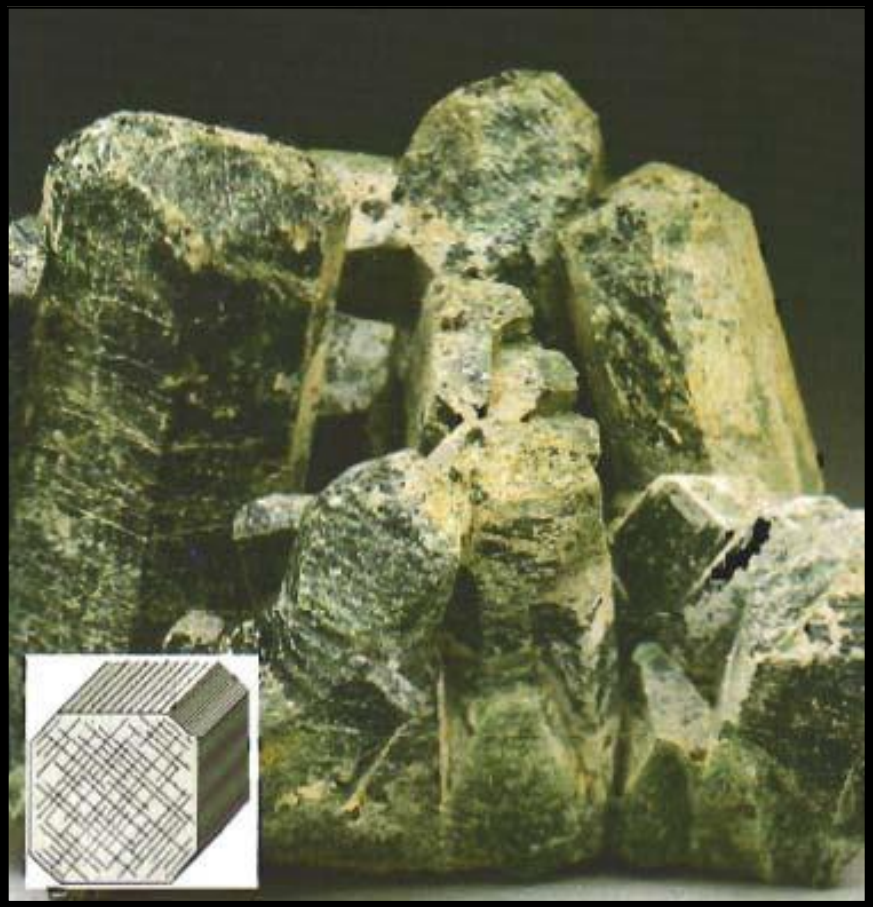


HORNBLEND

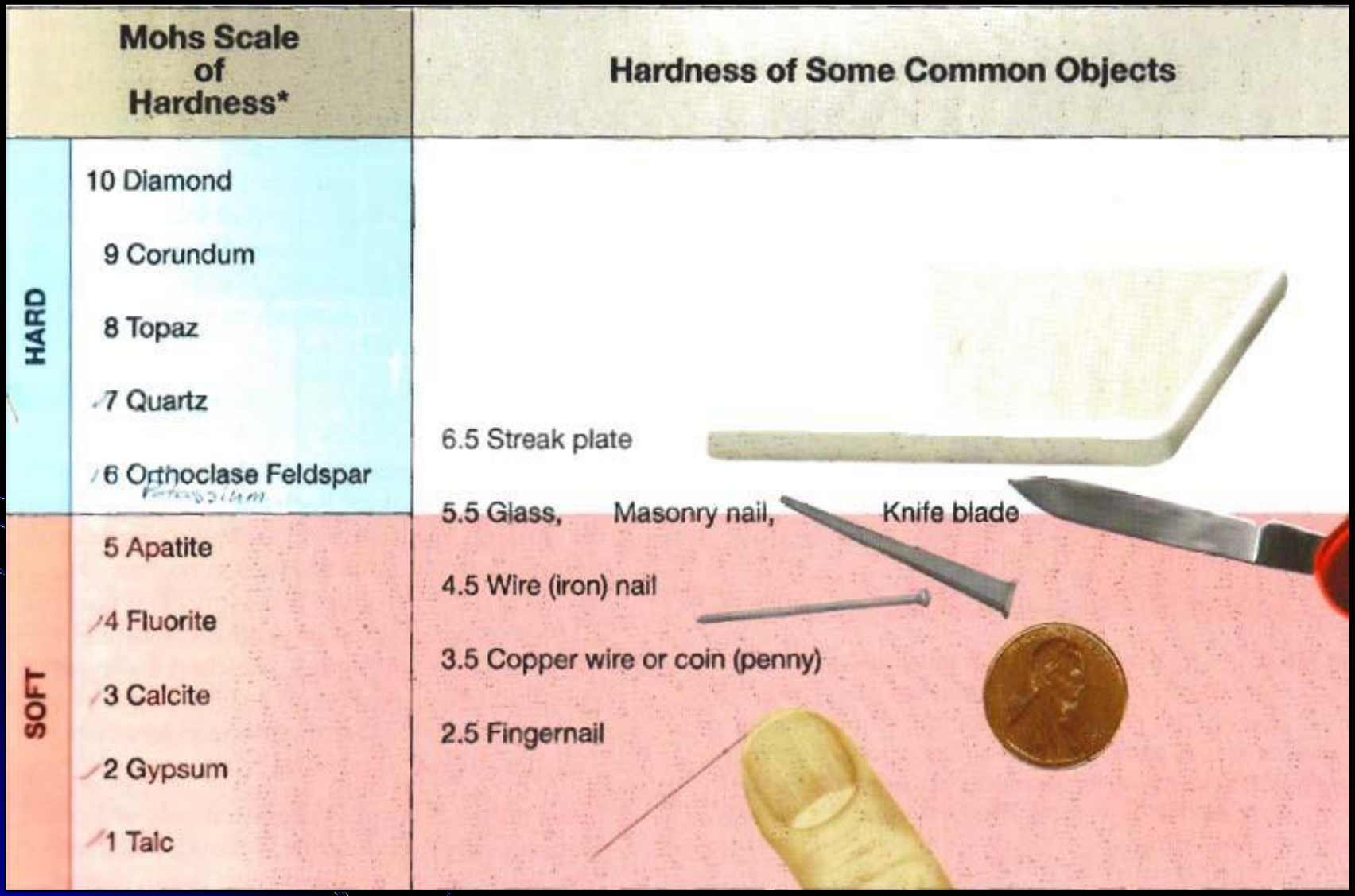


PYROXENE

CLEAVAGE

Mineral dan Batuan

Kristal & Mineral



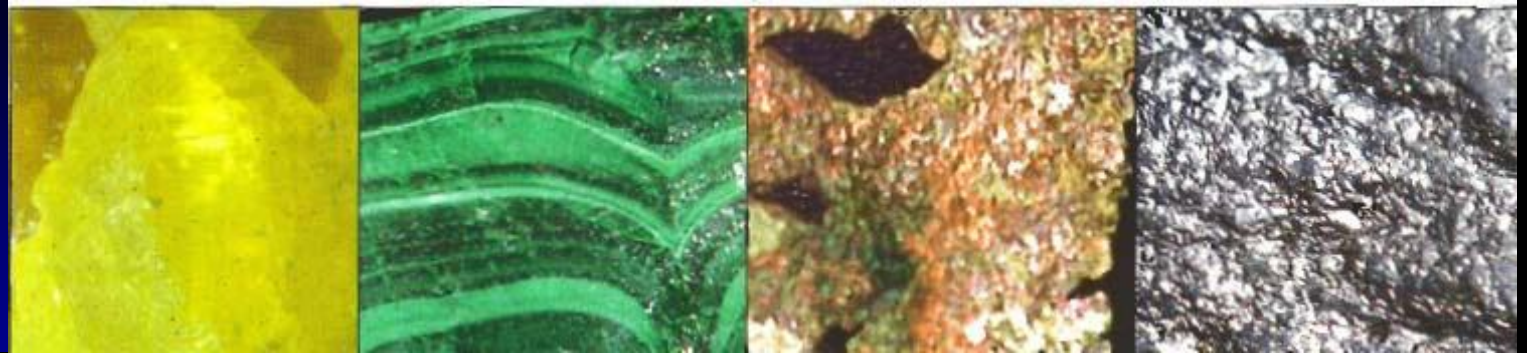
SKALA MOHS

Mineral dan Batuan

Kristal & Mineral

- **CALCITE DAN HCL**
- **WARNA**

SIFAT KHUSUS



Mineral dan Batuan

Geology ITB

Kristal & Mineral

MINERAL DATABASE (Alphabetical Listing)

Mineral	Luster	Hardness	Streak	Distinctive Properties	Some Uses
ACTINOLITE (amphibole)	Nonmetallic (NM)	5.5–6	White	Color dark green or pale green; Forms needles, prisms, and asbestose fibers; Good cleavage at 56° and 124°; SG = 3.1	Gemstone (Nephrite). Asbestose products
AMPHIBOLE: See HORNBLENDE and ACTINOLITE					
APATITE $Ca_5F(PO_4)_3$ calcium fluorophosphate	Nonmetallic (NM)	5	White	Color pale or dark green, brown, blue, white, or purple; Sometimes colorless; Transparent or opaque; Brittle; Conchoidal fracture; Forms hexagonal prisms; SG = 3.1–3.4	Used for pesticides and fertilizers
ASBESTOS: fibrous varieties of AMPHIBOLE and SERPENTINE					
AUGITE (pyroxene) calcium ferromagnesian silicate	Nonmetallic (NM)	5.5–6	White to pale gray	Color green to black; Forms opaque, short, 8-sided prisms; Two good cleavages that intersect at 87° and 93° (nearly right angles); SG = 3.2–3.5	Some pyroxene mined as an ore of lithium, for making steel
AZURITE $Cu_3(CO_3)_2(OH)_2$ hydrous copper carbonate	Nonmetallic (NM)	3.5–4	Light blue	Color a distinctive deep blue; Forms crusts of small crystals, opaque earthy masses, or short and long prisms; Brittle; Effervesces in dilute HCl; SG = 3.7–3.8	Ore of copper for pipes, electrical circuits, coins, ammunition, gemstone
BARITE $BaSO_4$ barium sulfate	Nonmetallic (NM)	3–3.5	White	Colorless to white, with tints of brown, yellow, blue, or red; Forms short tabular crystals and rose-shaped masses (Barite roses); Brittle; Cleavage good to excellent; Very heavy; SG = 4.5	Used in rubber, paint, glass, oil-well drilling fluids
BAUXITE Mixture of aluminum hydroxides	Nonmetallic (NM)	1–3	White	Brown earthy rock with shades of gray, white, and yellow; Amorphous; Often contains rounded pea-sized structures with laminations; SG = 2.3	Ore of Aluminum
BIOTITE MICA ferromagnesian potassium, hydrous aluminum silicate	Nonmetallic (NM)	2.5–3	Gray-brown	Color black, green-black, or brown-black; Cleavage excellent; Forms very short prisms that split easily into very thin, flexible sheets; SG = 2.7–3.1	Used for fire-resistant tiles, rubber, paint
BORNITE Cu_5FeS_4 copper-iron sulfide	Metallic (M)	3	Dark gray to black	Color opaque silvery blue or copper-red; Tarnishes to iridescent purple and blue; Forms dense, brittle masses; Cleavage poor to absent	Ore of copper for pipes, electrical circuits, coins, ammunition, brass, bronze
CALCITE $CaCO_3$ calcium carbonate	Nonmetallic (NM)	3	White	Usually colorless, white, or yellow, but may be green, brown, or pink; Opaque or transparent; Excellent cleavage in 3 directions not at 90°; Forms prisms, rhombohedrons, or scalenohedrons that break into rhombohedrons; Effervesces in dilute HCl; SG = 2.7	Used to make antacid tablets, fertilizer, cement; Ore of calcium
CHALCEDONY SiO_2 cryptocrystalline quartz	Nonmetallic (NM)	7	White	Colorless, white, yellow, light brown, or other pastel colors in combinations; Often translucent; Conchoidal fracture; Luster waxy; Cryptocrystalline; SG = 2.5–2.6	Used as an abrasive; Used to make glass, gemstones (agate, chrysoprase)

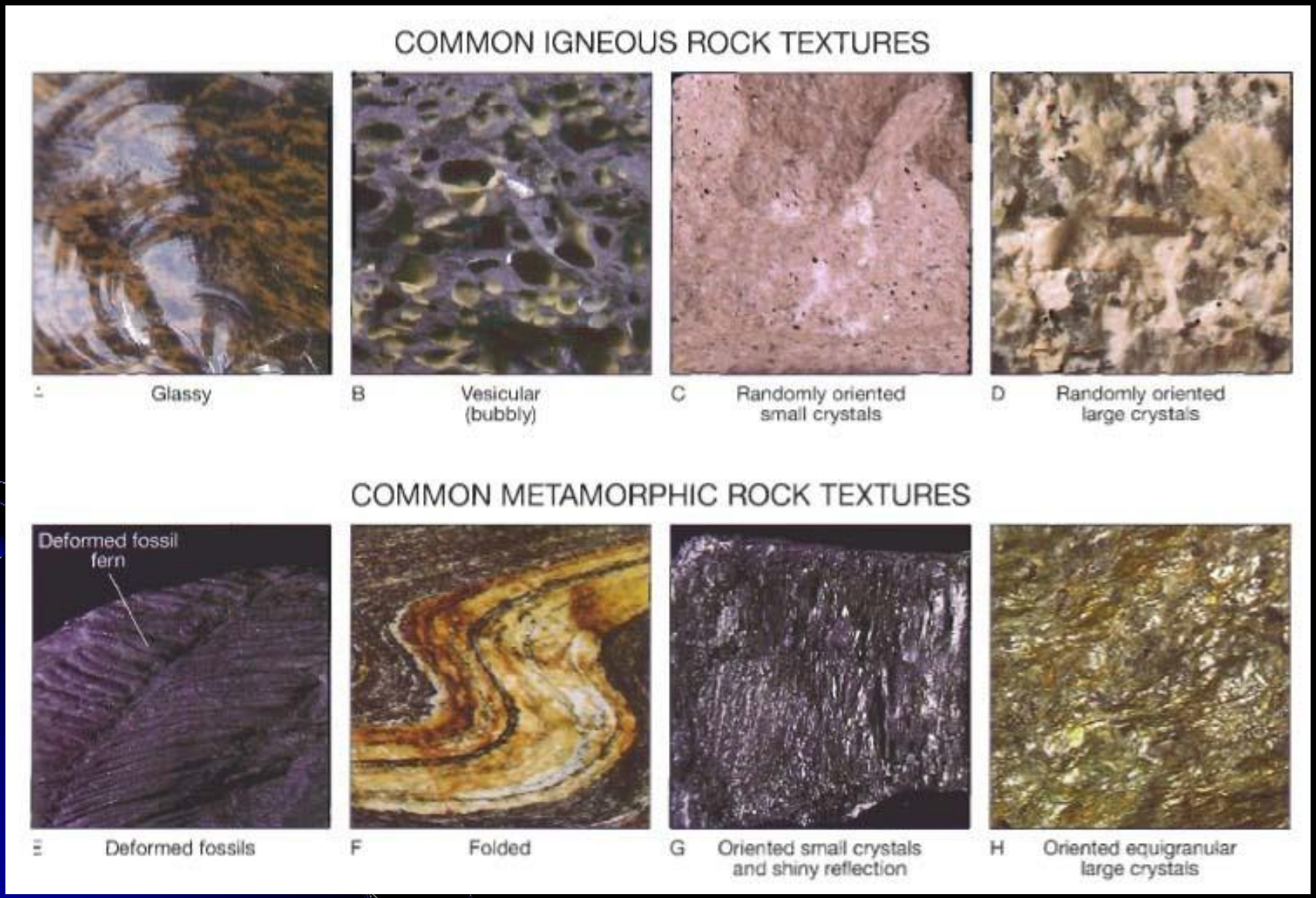
MINERAL DATABASE (Alphabetical Listing)

Mineral	Luster	Hardness	Streak	Distinctive Properties	Some Uses
CHALCOPYRITE $CuFeS_2$ copper-iron sulfide	Metallic (M)	3.5–4	Dark gray	Color golden or brassy yellow; Tarnishes brown, or iridescent blue, green, and red; Forms elongate tetrahedra; Brittle; Cleavage poor; SG = 4.1–4.3	Ore of copper for pipes, electrical circuits, coins, ammunition, brass, bronze
CHERT SiO_2 cryptocrystaline quartz	Nonmetallic (NM)	7	White	Opaque gray or white; Luster waxy; Conchoidal fracture; SG = 2.5–2.8	Used as an abrasive; Used to make glass, gemstones
CHLORITE ferromagnesian aluminum silicate	Nonmetallic (NM)	2–2.5	White	Color dark green; Cleavage excellent; Forms short prisms that split easily into thin flexible sheets; Luster shiny or dull; SG = 2–3	Used for fire-resistant tiles, rubber, paint, art sculpture medium
CHROMITE $FeCr_2O_4$ iron-chromium oxide	Metallic (M)	5.5–6	Dark brown	Color silvery black to black; Tarnishes gray; Forms octahedrons; Brittle; No cleavage; May be weakly magnetic; SG = 4.6–4.8	Ore of chromium for making chrome, stainless steel, mirrors, paint and used in leather tanning
CHRYSOCOLLA $CuSiO_3 \cdot 2H_2O$ hydrated copper silicate	Nonmetallic (NM)	2–4	Very light blue	Color pale blue to blue-green; Opaque; Forms amorphous crusts or may be massive; Conchoidal fracture; Luster shiny or earthy; SG = 2.0–2.4	Ore of copper for pipes, electrical circuits, coins, ammunition; gemstone
COPPER (NATIVE COPPER) Cu copper	Metallic (M)	2.5–3	Copper	Color copper; Tarnishes brown or green; Forms distorted cubes octahedrons, and dendritic (leaf-like) masses; Malleable; Opaque; Cleavage absent; SG = 8.8–8.9	Ore of copper for pipes, electrical circuits, coins, ammunition, brass, bronze
CORUNDUM Al_2O_3 aluminum oxide	Nonmetallic (NM)	9	White	Color gray, blue, red, brown; Transparent or opaque; Forms short hexagonal prisms with striated flat ends; Cleavage absent; SG = 3.9–4.1	Used for abrasive powders to polish lenses; gemstones (red ruby, blue sapphire)
DOLOMITE $CaMg(CO_3)_2$ magnesian calcium carbonate	Nonmetallic (NM)	3.5–4	White	Color white, gray, yellow, or pink; Usually opaque; Cleavage excellent in 3 directions; Breaks into rhombohedrons; Reacts like calcite, but will effervesce in dilute HCl only if powdered; SG = 2.8–2.9	Ore of magnesium metal; soft abrasive; used to make paper
EPIDOTE complex silicate	Nonmetallic (NM)	6–7	White	Color pale or dark green to yellow-green; Massive or forms striated prisms; Cleavage poor; SG = 3.3–3.5	Gemstone
FELDSPAR: See PLAGIOCLASE (Na-Ca Feldspars) and POTASSIUM FELDSPAR (K-Spar)					
FLINT SiO_2 cryptocrystalline quartz	Nonmetallic (NM)	7	White	Color black to very dark gray; Opaque to translucent; Conchoidal fracture; Cryptocrystaline; SG = 2.5–2.6	Used as an abrasive; Used to make glass, gemstones
FLUORITE CaF_2 calcium fluoride	Nonmetallic (NM)	4	White	Colorless, purple, blue, gray, green, or yellow; Cleavage excellent; Crystals usually cubes; Transparent or opaque; Brittle; SG = 3.0–3.3	Source of fluorine for processing aluminum; flux in steel making

DATABASE MINERAL

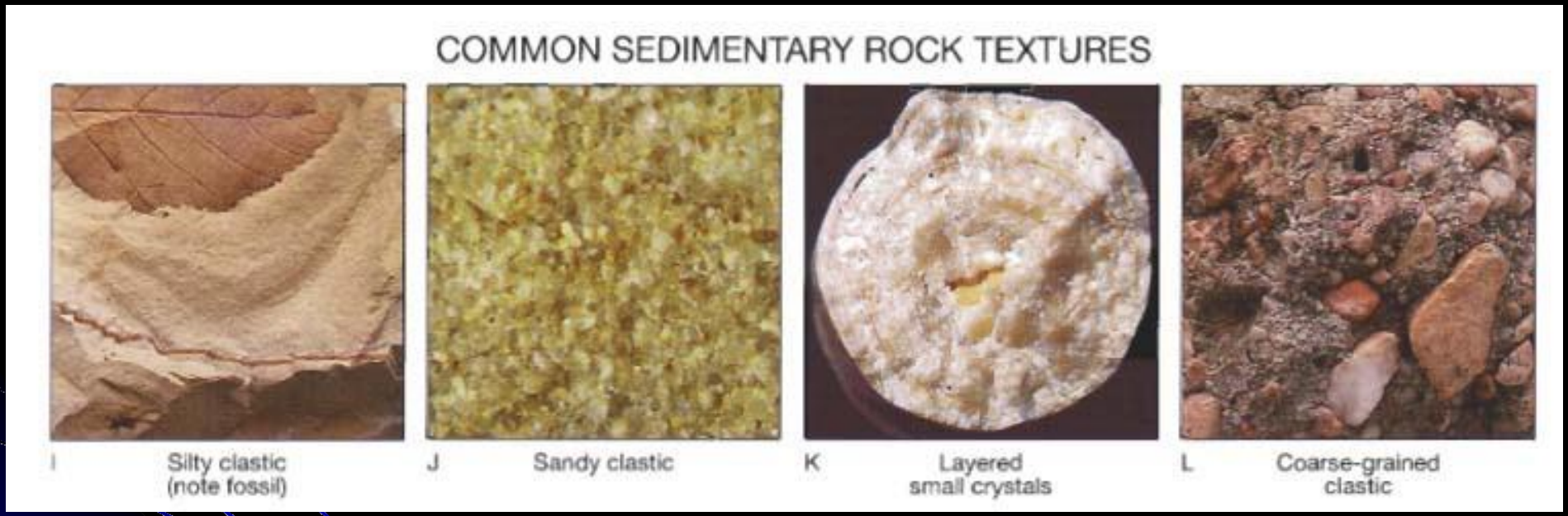
Mineral dan Batuan

Kristal & Mineral



Mineral dan Batuan

Kristal & Mineral



Mineral dan Batuan

Kristal & Mineral

Figure 1.5 Quartz crystal.

Figure 1.6 Rose quartz.

Figure 1.7 Smoky quartz.

Figure 1.8 Cryptocrystalline quartz (chert).

Figure 1.9 Orthoclase (microcline).

Figure 1.10 Plagioclase.

Figure 1.11 Gypsum (selenite).

Figure 1.12 Talc.

Figure 1.13 Calcite (note double refraction).

Figure 1.14 Fluorite.

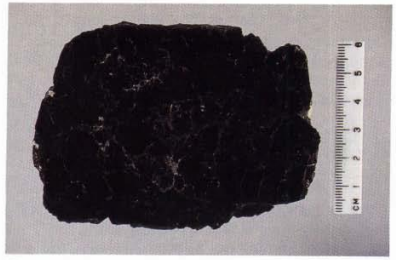


Figure 1.15 Biotite.

Figure 1.16 Olivine.

Figure 1.17 Hematite (specularite).

Figure 1.18 Hematite.

Figure 1.19 Goethite (limonite).

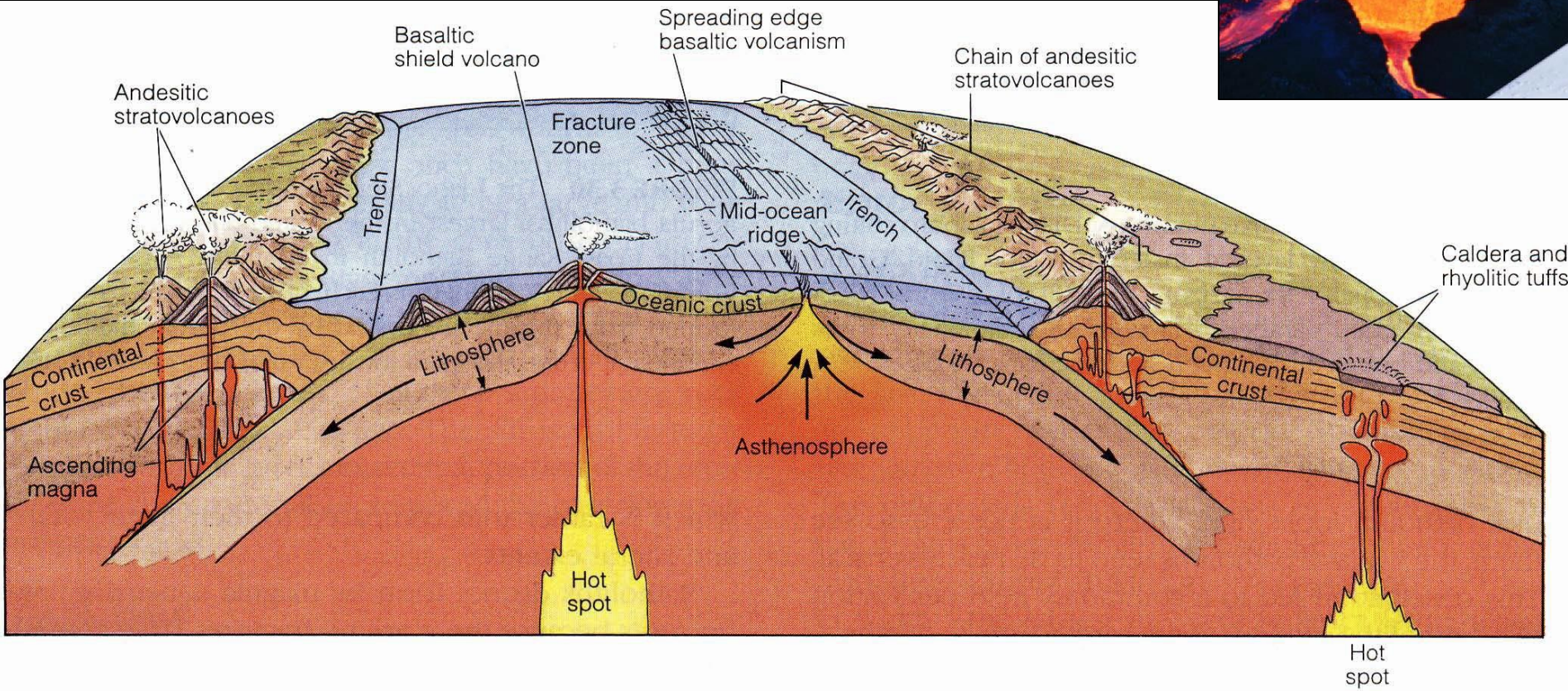
Figure 1.20 Pyrite.

THE ORIGIN OF ROCKS

Igneous Rocks

Origin

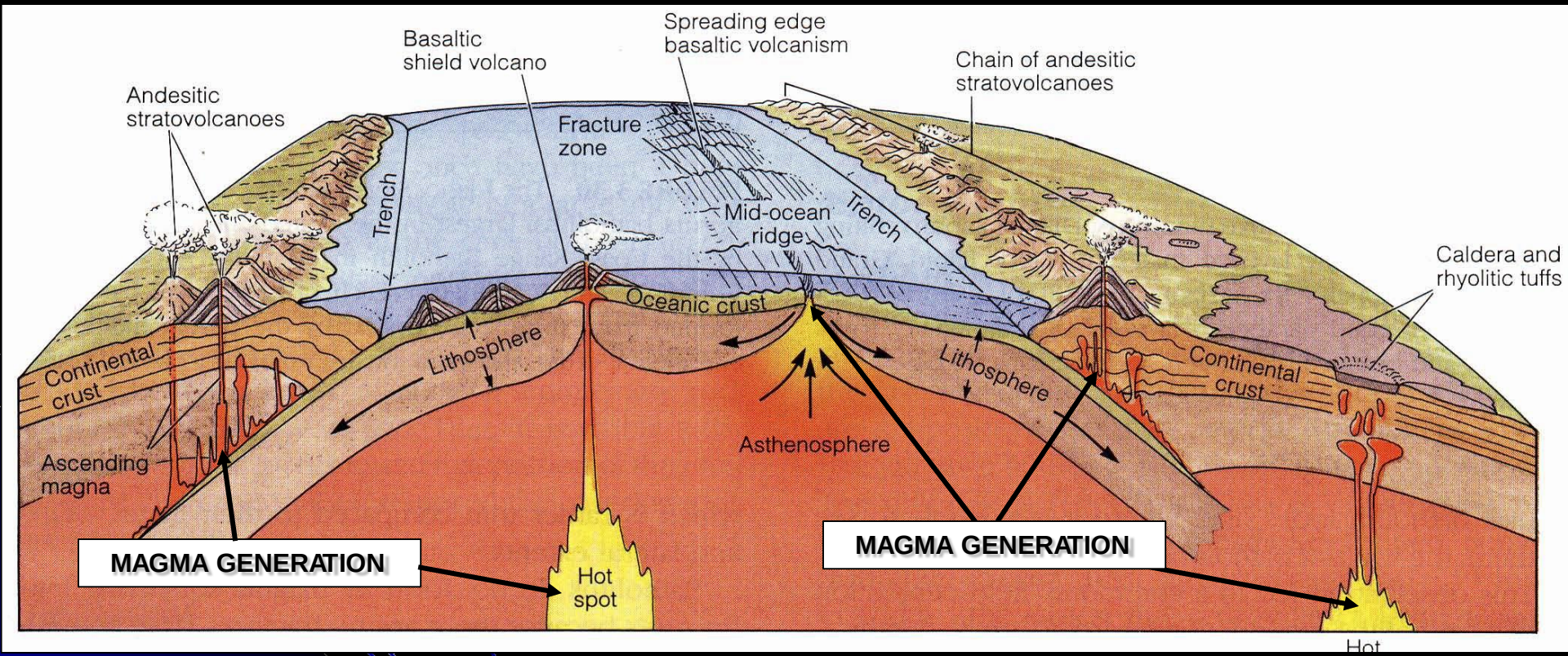
PLATE TECTONICS & ORIGIN OF ROCKS



Igneous Rocks

Origin

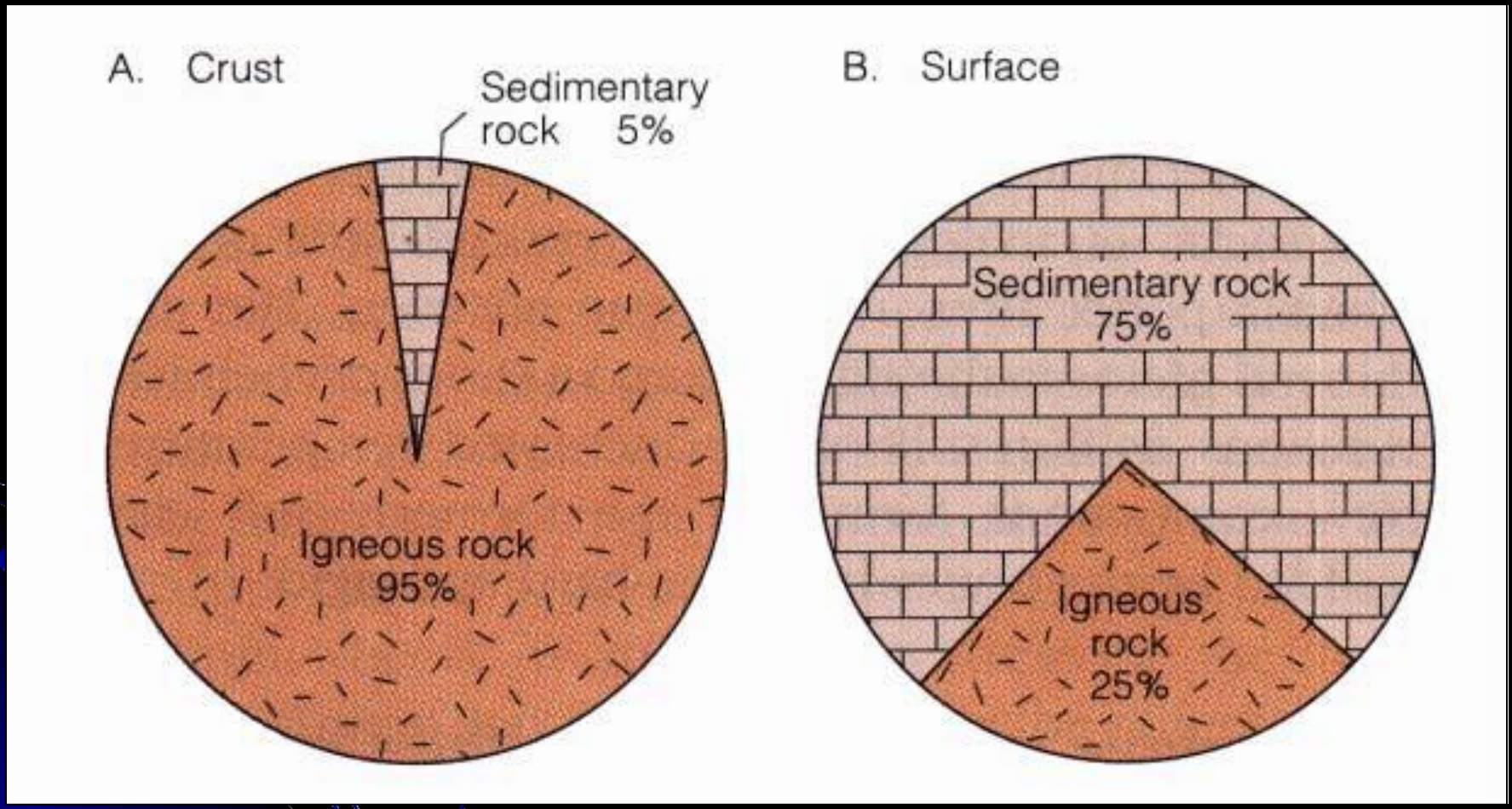
PLATE TECTONICS & ORIGIN OF ROCKS



Geology ITB

Earth Crust

Sedimentary vs Ign Rocks



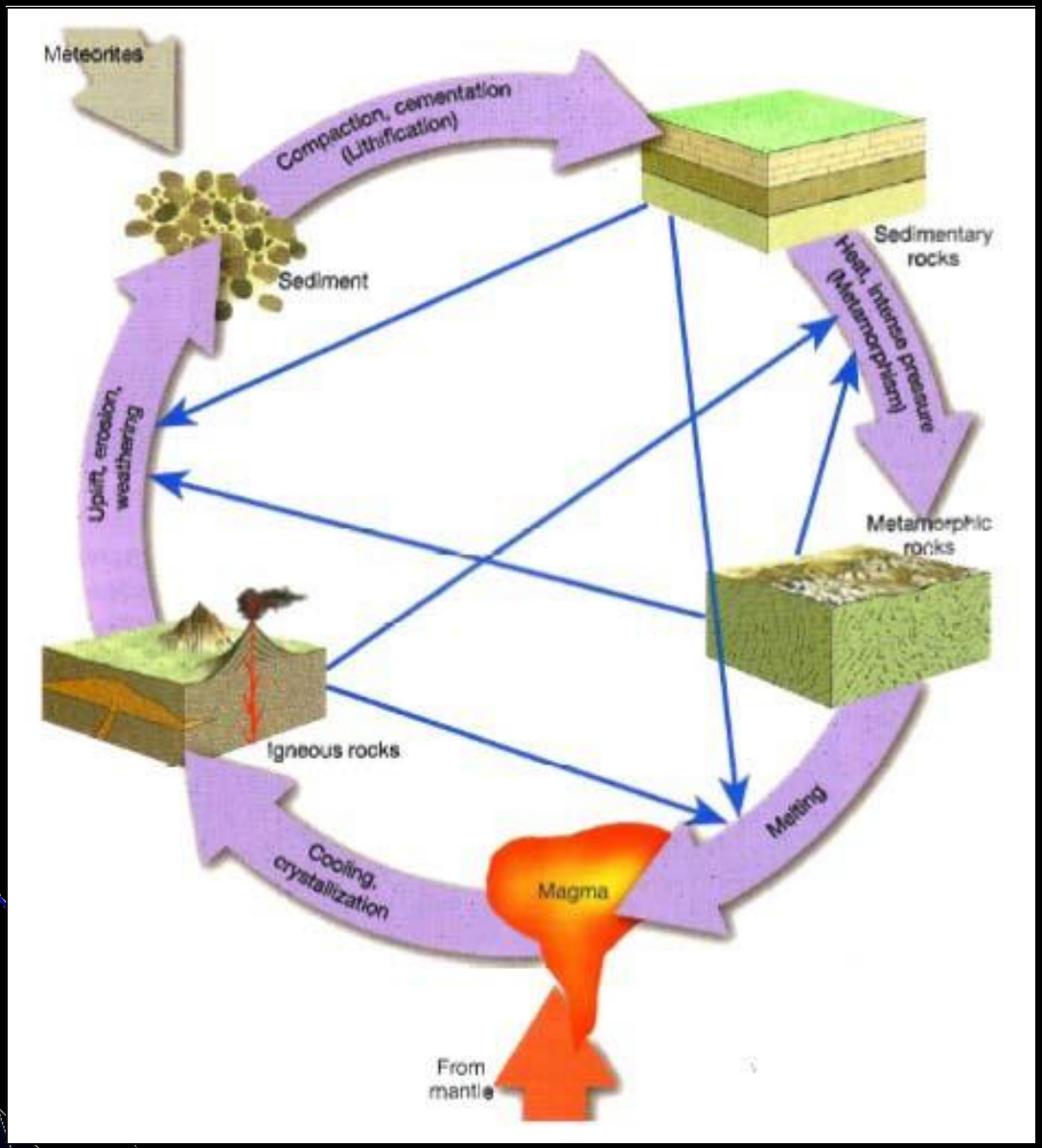
Rock distribution

Geology ITB

Earth Crust

Rocks Cycle

ROCK CYCLES

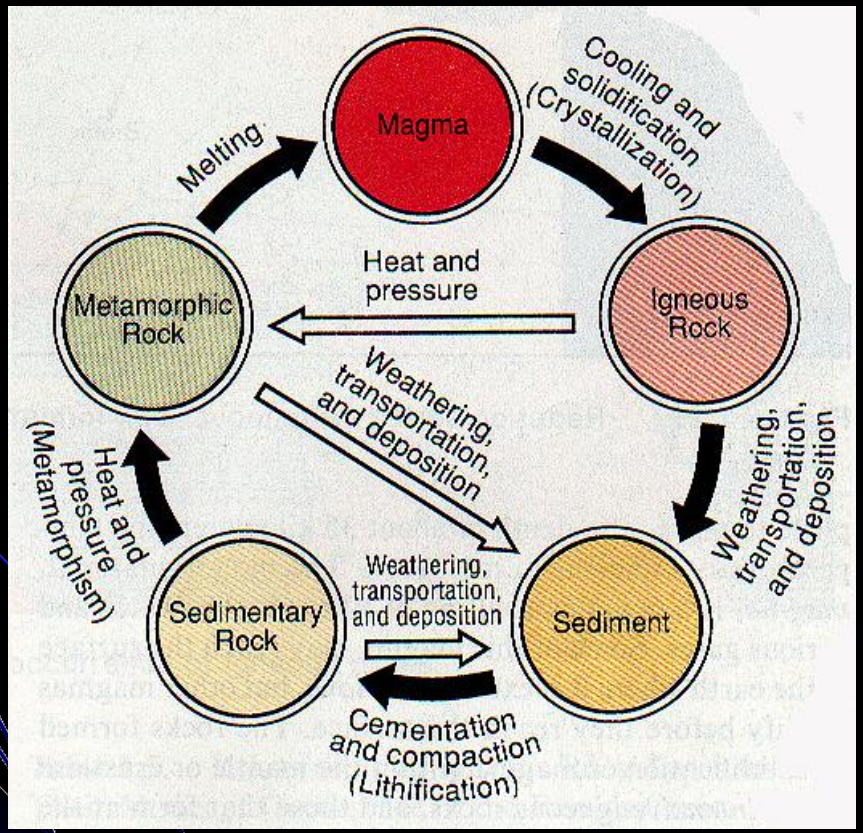


Geology ITB

Earth Crust

Rocks Cycle

Siklus Batuan mengambarkan proses interaksi dan transformasi dari tiga kelompok batuan. Proses ini dikontrol oleh proses internal seperti tektonik dan eksternal yaitu udara dan air.



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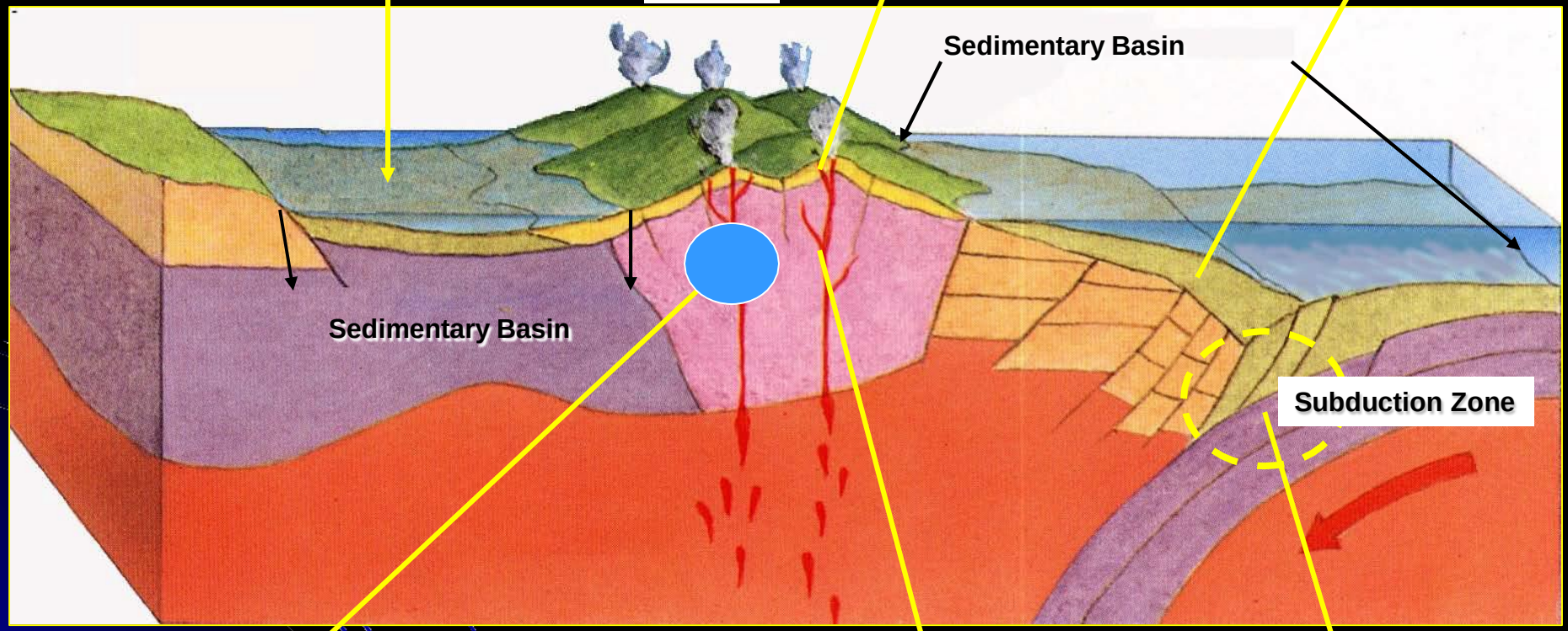
Earth Crust

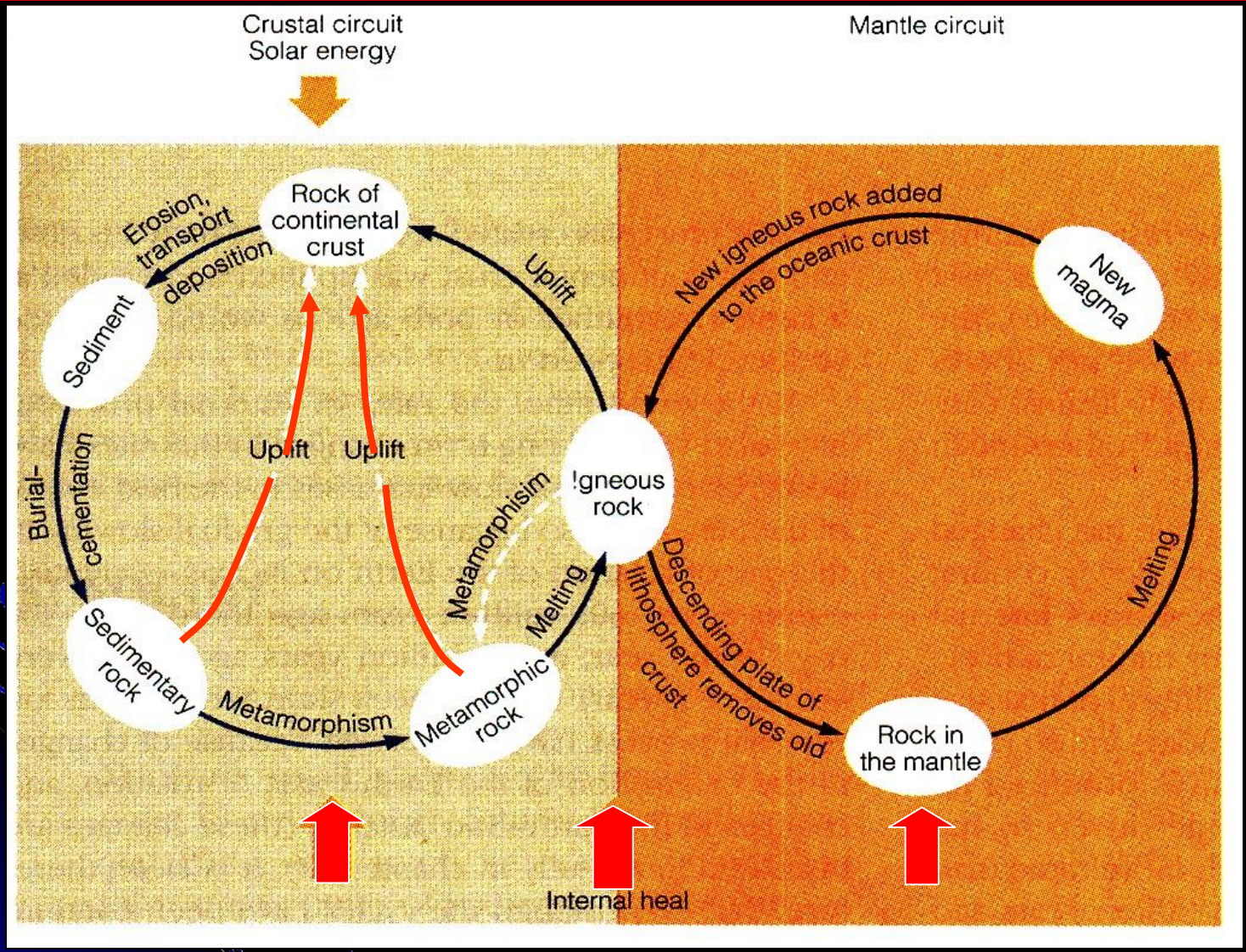
Rocks Cycle



Geology ITB

Earth Crust

Rocks vs Tectonic Cycle

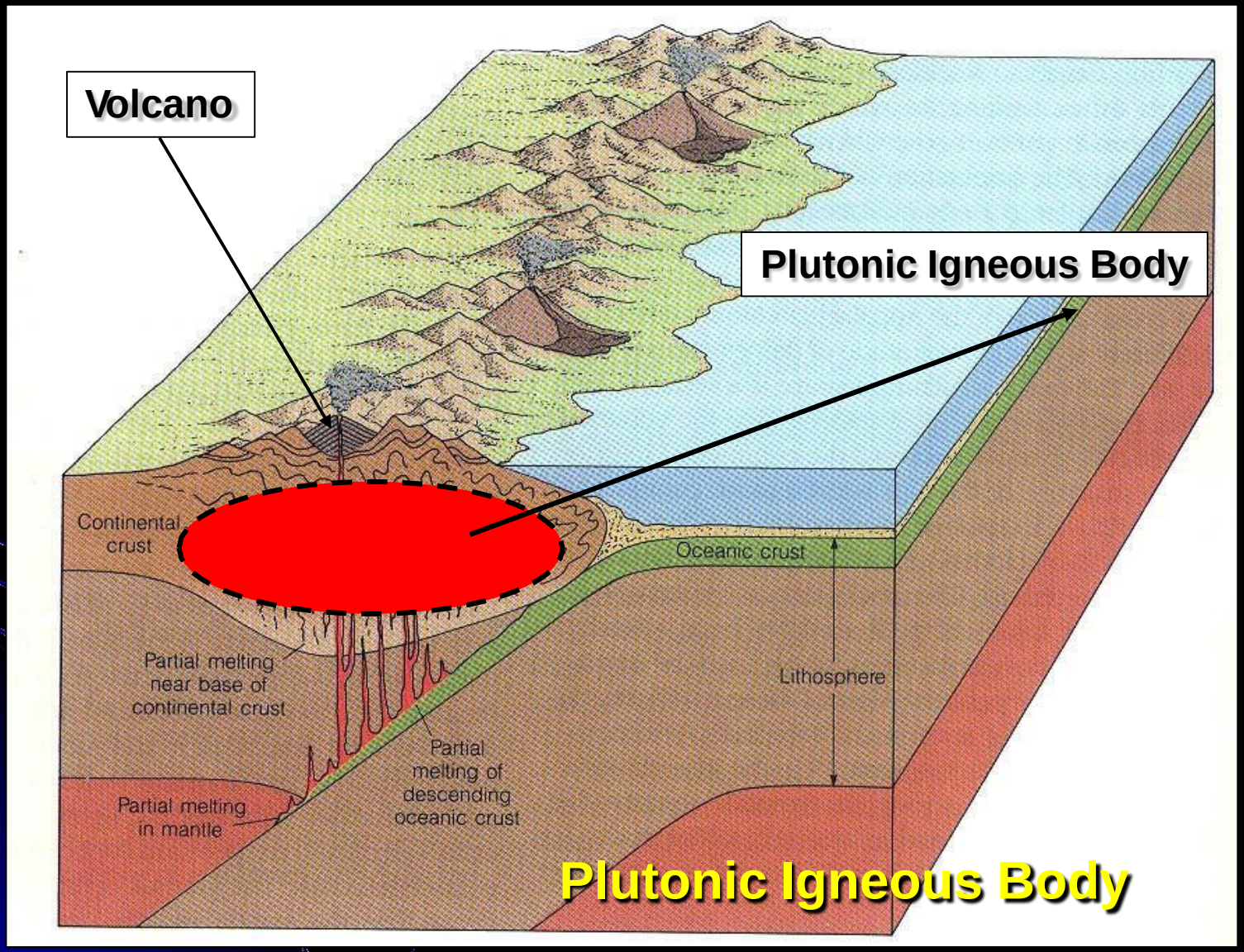


Rock Cycle & Plate Tectonics

Geology ITB

Igneous Rocks

Plutonic vs Volcanic



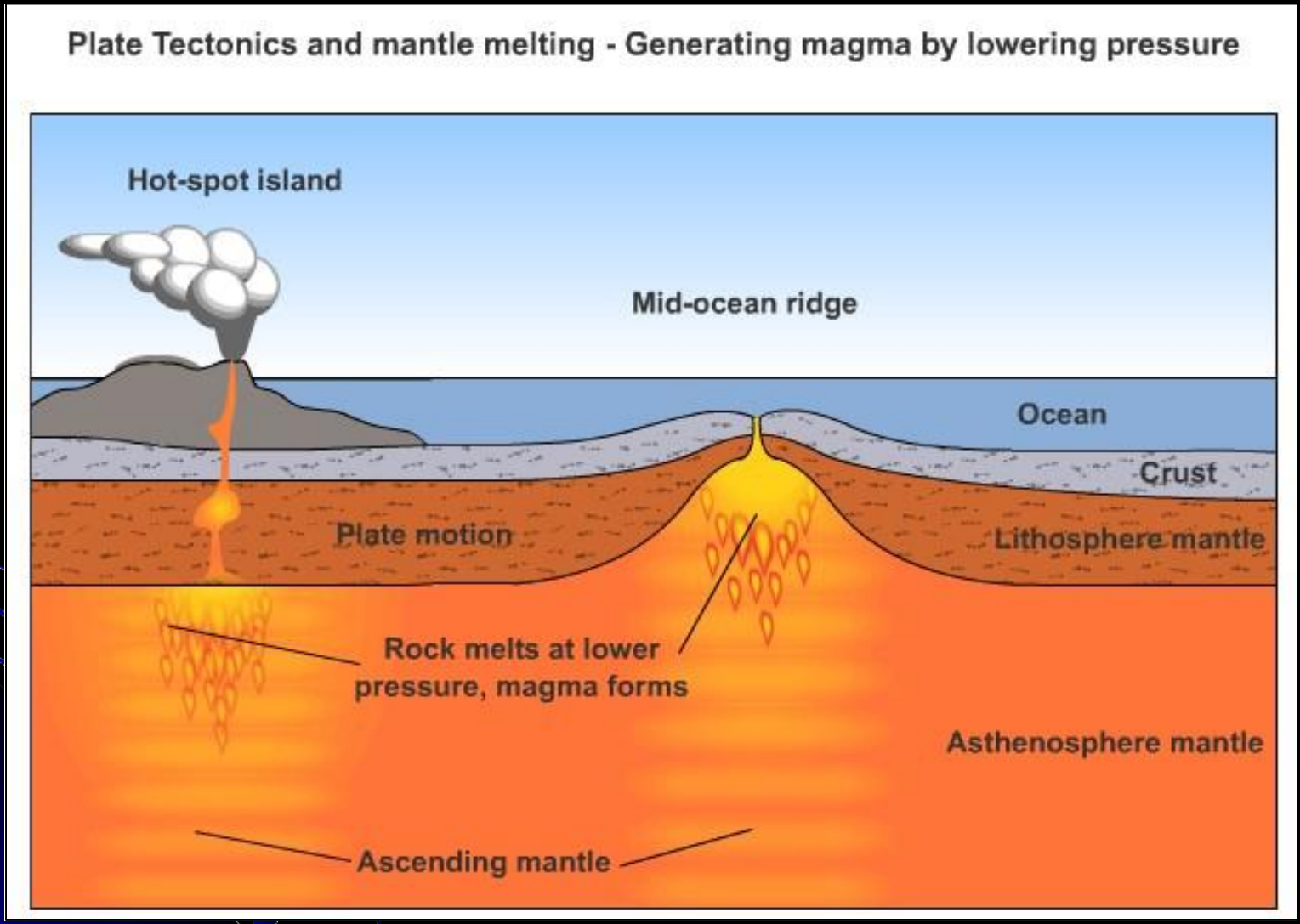
Geology ITB

Igneous Rocks

Plutonic vs Volcanic

EXTRUSI VE (VOLCANIC)

Origin of Igneous Rocks



MAGMA GENERATION IN SPREADING CENTER

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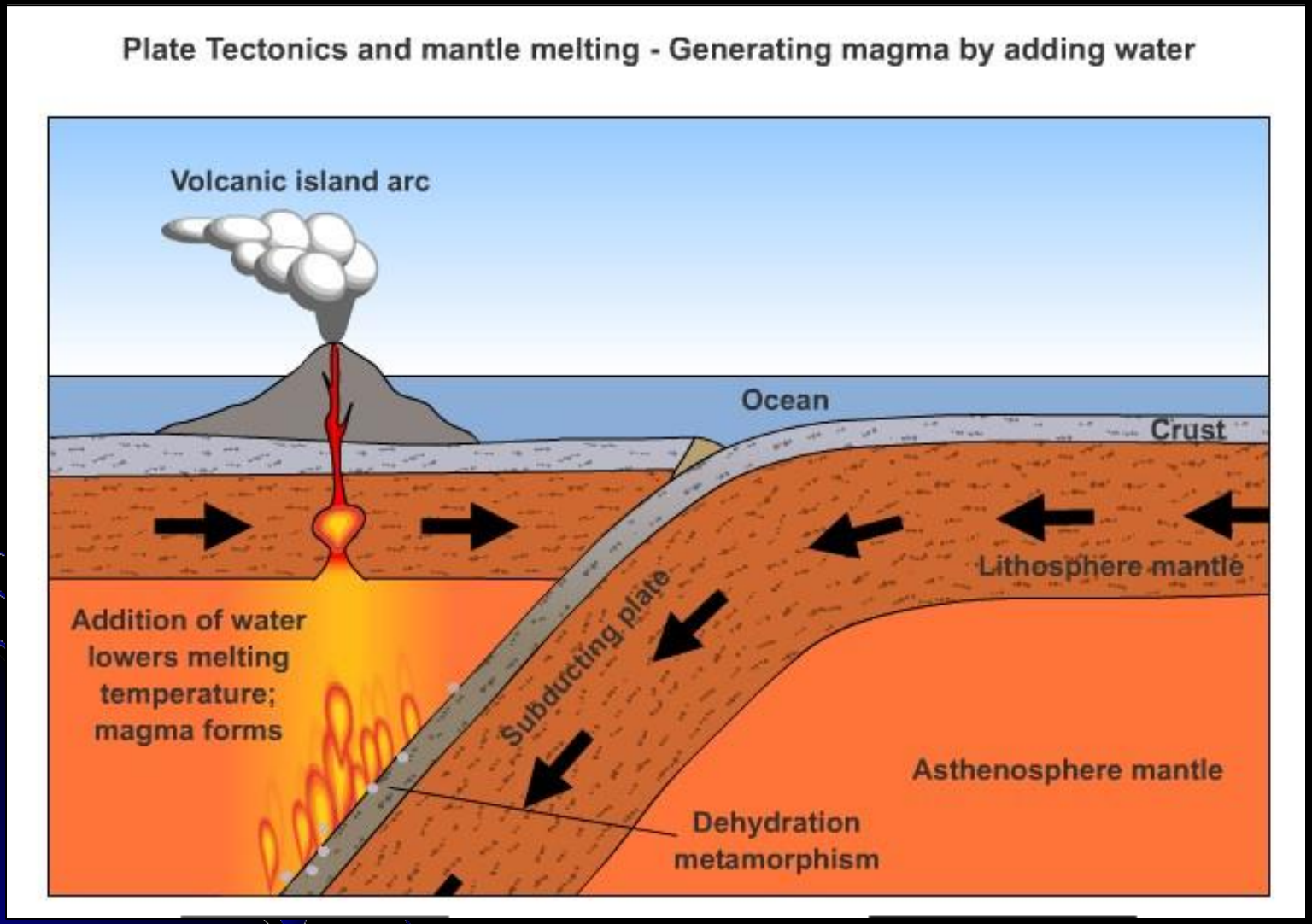
Igneous Rocks

Plutonic vs Volcanic



MAGMA GENERATION IN SUBDUCTION ZONE

Igneous Rocks

Plutonic vs Volcanic

- **Mineral diawali kristalisasi dari magma dan lava sesudah inti kristal kecil terbentuk dan berkembang.**

- **Pendinginan cepat yang umumnya terjadi pada batuan vulkanik dan membentuk batuan yang bertekstur afanitik (berbutir halus).**

- **Pendinginan perlahan dari batuan plutonik menghasilkan batuan bertexture fanerik (berbutir kasar).**

Igneous Rocks

Plutonic vs Volcanic

Klasifikasi, Texture dan Komposisi

- Klasifikasi batuan beku didasarkan pada **texture dan komposisi**.
- **Batuan beku volkanik** bertexture afanitik atau porfiritik termasuk: **riolit, andesit, basalt dan tuff**.
- **Batuan beku plutonik** bertexture fanerik termasuk: **granit, gabro dan diorit**.

Igneous Rocks

Komposisi dan Texture Batuan Beku

- Berdasarkan komposisi batuan beku dibagi menjadi dua yaitu: **Felsic (asam) seperti granit dan riolit dan Mafik (basa) seperti gabro, diorit dan basalt**.

- Sedangkan batuan beku yang komposisinya **intermedier termasuk granodiorit dan andesit.**

- **Pluton** adalah tubuh batuan beku yang mengintrusi batuan samping atau yang membeku jauh dibawah permukaan bumi. Intrusi diklasifikasikan berdasarkan volume dan geometri. Intrusi yang **konkordan termasuk sill daan lakolit. Intrusi diskordan termasuk dike, vulkanik neck, batolit dan stock**.

- **Batolit** adalah batuan plutonik yang besar dengan luas permukaan $\pm$ 100km^2. Stock adalah batolit dengan ukuran jauh lebih kecil.

Igneous Rocks

Mafic vs Felsic

- **Secara umum ada dua jenis magma :**
  - **Asam (Felsic)**
  - **Basa (Mafic)**
- **Pada kondisi ideal pendinginan magma yang mafic (basa) akan memberikan sekuen mineral yang berbeda yang stabil pada kondisi temperatur tertentu yang dinamakan sebagai deret atau seri reaksi Bowen.**

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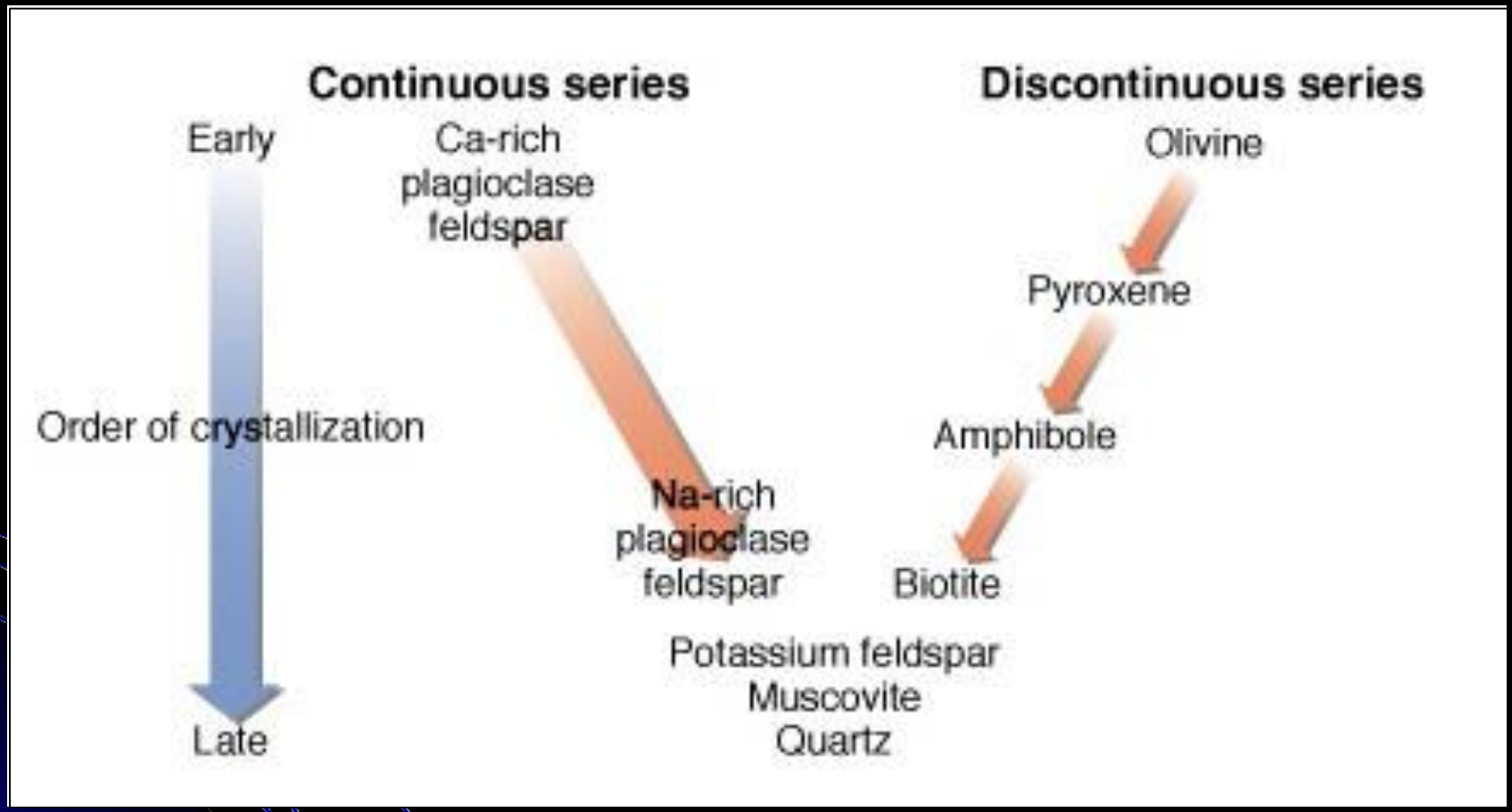
Igneous Rocks

Bowen Series

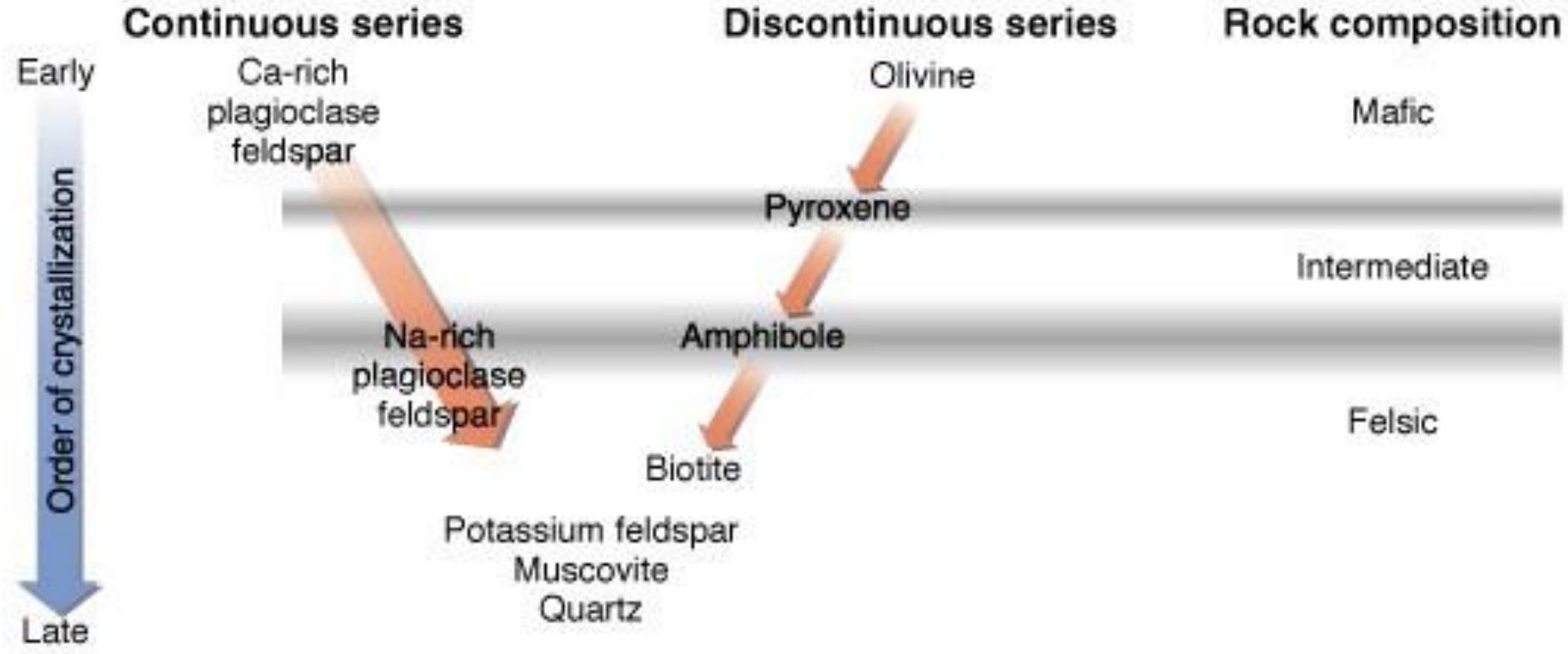


Bowen Reaction Series

Geology ITB

Igneous Rocks

Bowen Series



Bowen Reaction Series & Major Igneous Rocks

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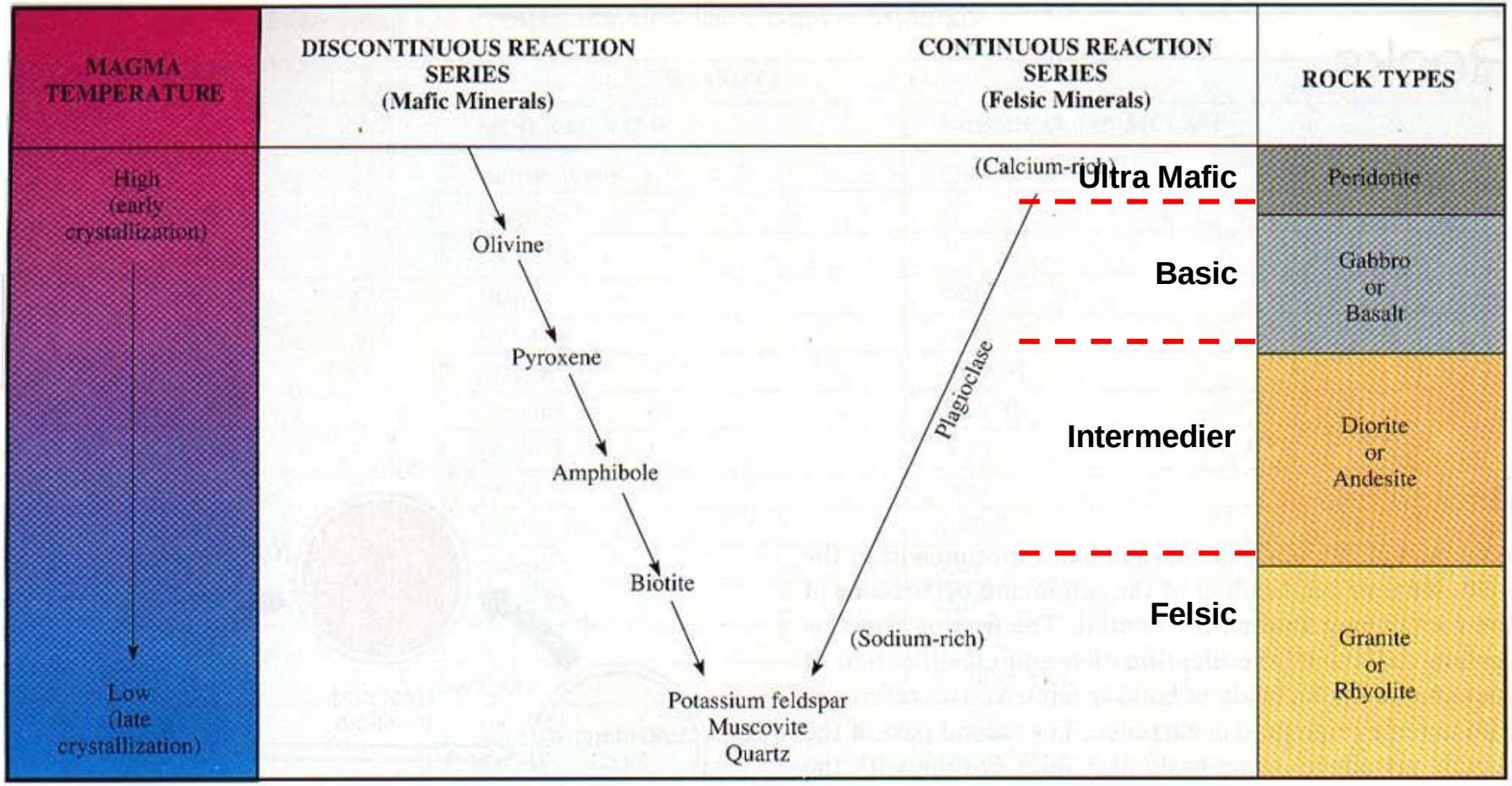
Igneous Rocks

Bowen Series



Reaction series for igneous rock formation from a magma.

Major Igneous Rocks

Igneous Rocks

Major Classification

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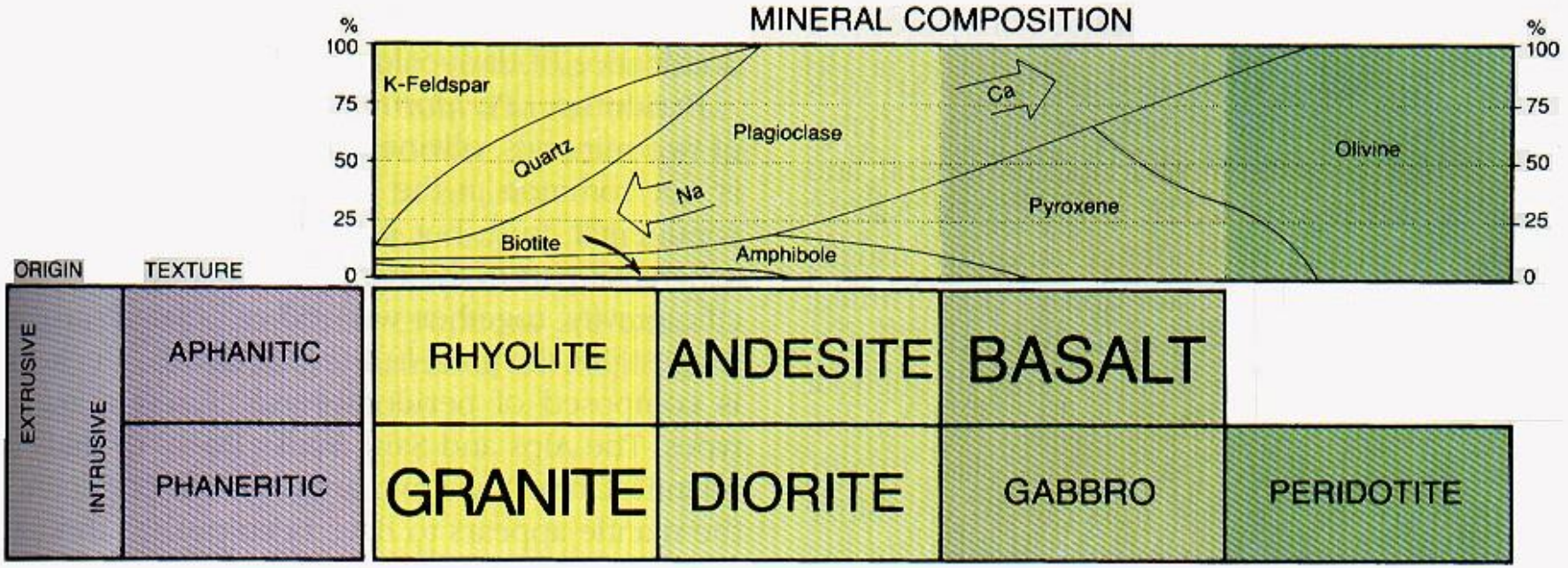

The classification of igneous rocks is based on texture (shown vertically on the chart) and composition (shown horizontally). The size of type in which the names of the rocks are printed is roughly proportional to their abundance.

Igneous Rock Classification

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Igneous Rocks

Intrusive vs. Extrusive

Relationship of Igneous Rock Types to Their Modes of Occurrence in the Earth's Crust.

	ROCK TYPE	SOME MODES OF OCCURRENCE
EXTRUSIVE	Pumice Scoria	Lava flows, pyroclastics Crusts on lava flows, pyroclastics
	Obsidian	Lava flows
	Rhyolite Andesite Basalt	Lava flows, shallow intrusives
INTRUSIVE	Rhyolite porphyry Andesite porphyry Basalt porphyry	Dikes, sills, laccoliths, intruded at medium to shallow depths
	Granite Diorite Gabbro Peridotite	Batholiths and stocks of deep-seated intrusive origin

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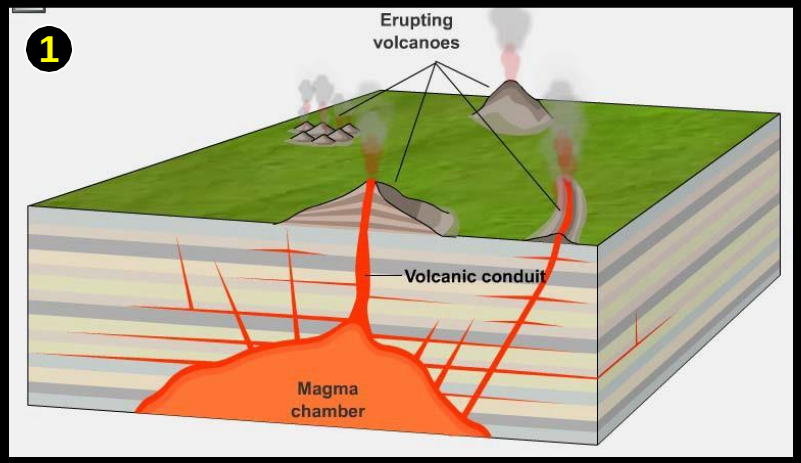
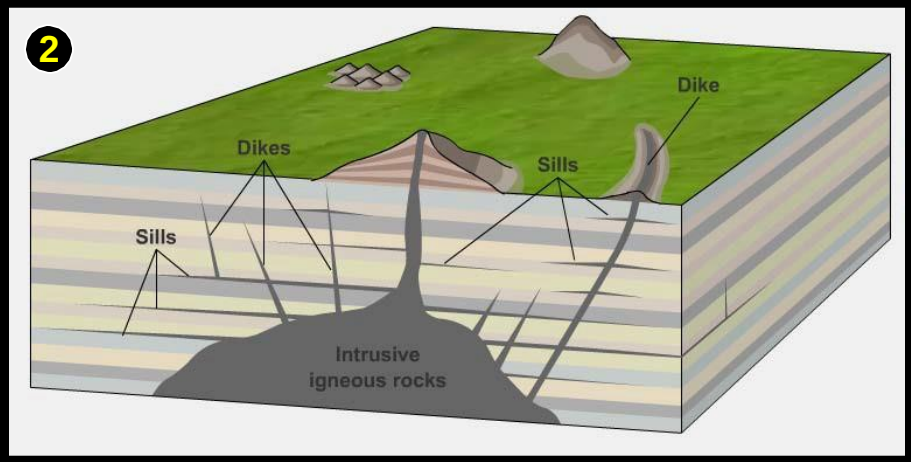
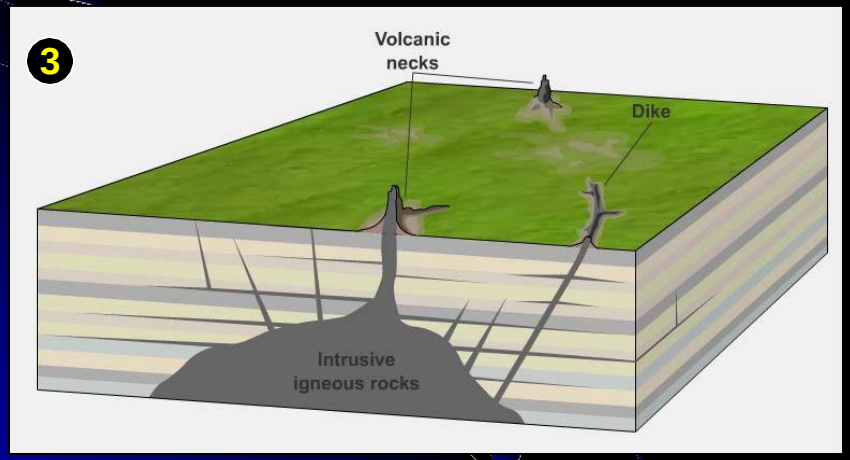
Igneous Rocks

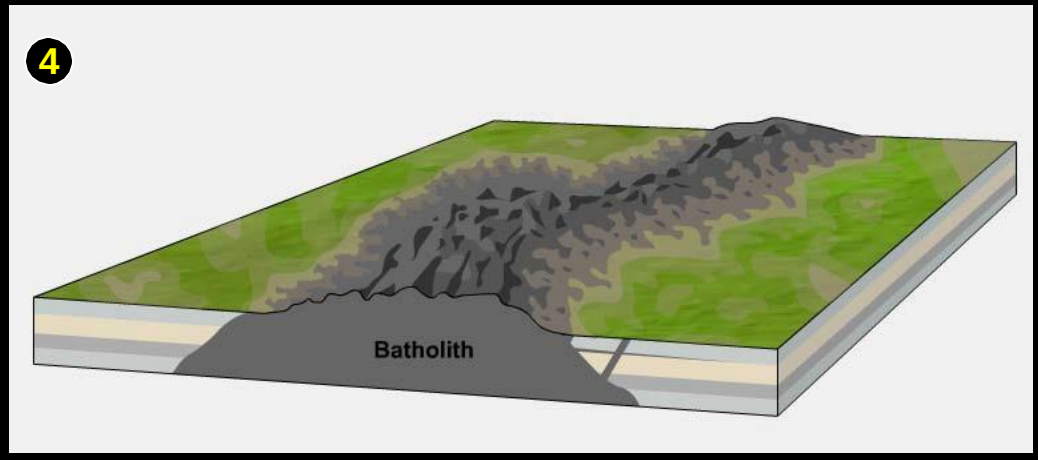
Igneous Body



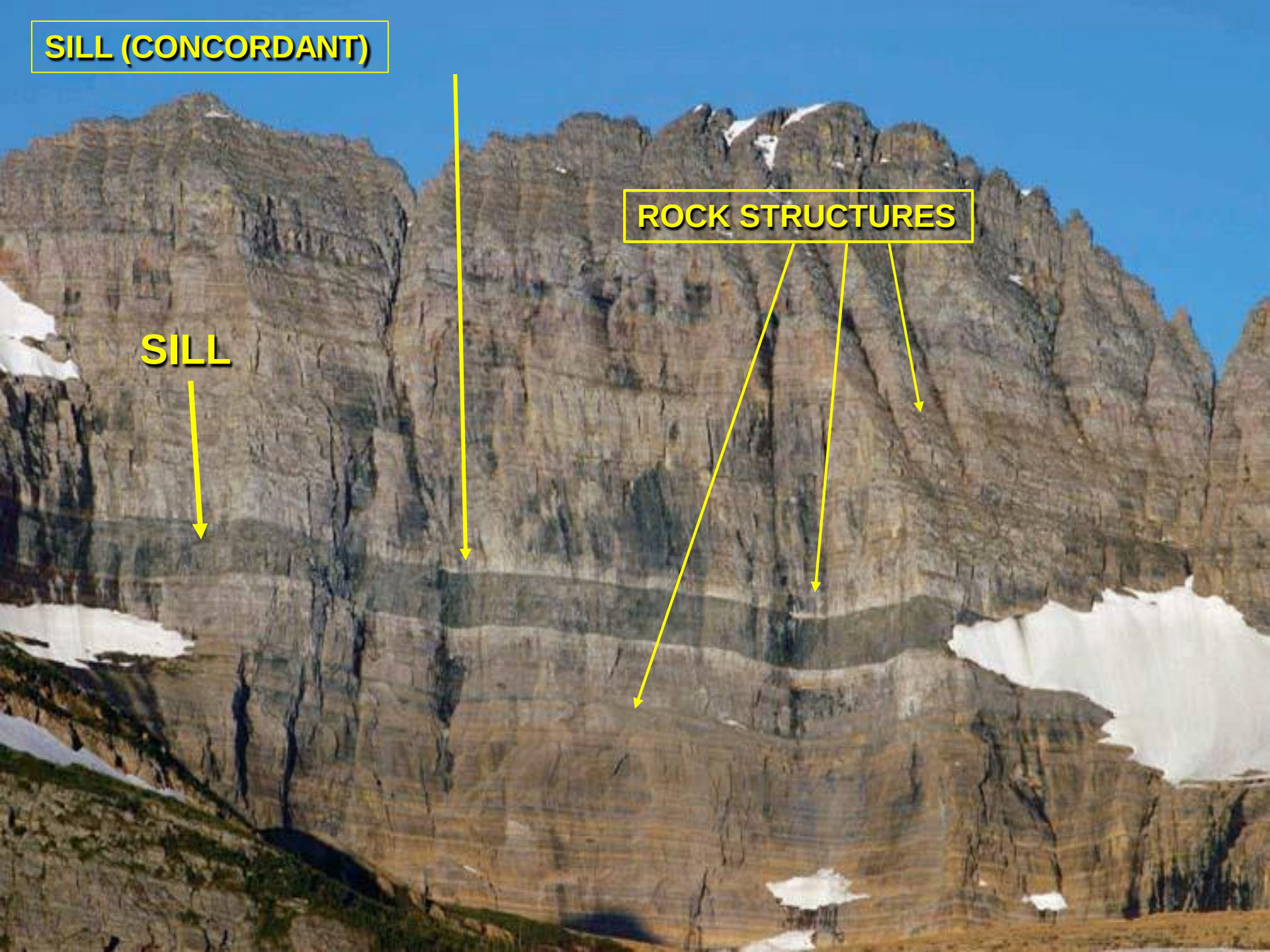


GEOMETRY OF IGNEOUS BODY





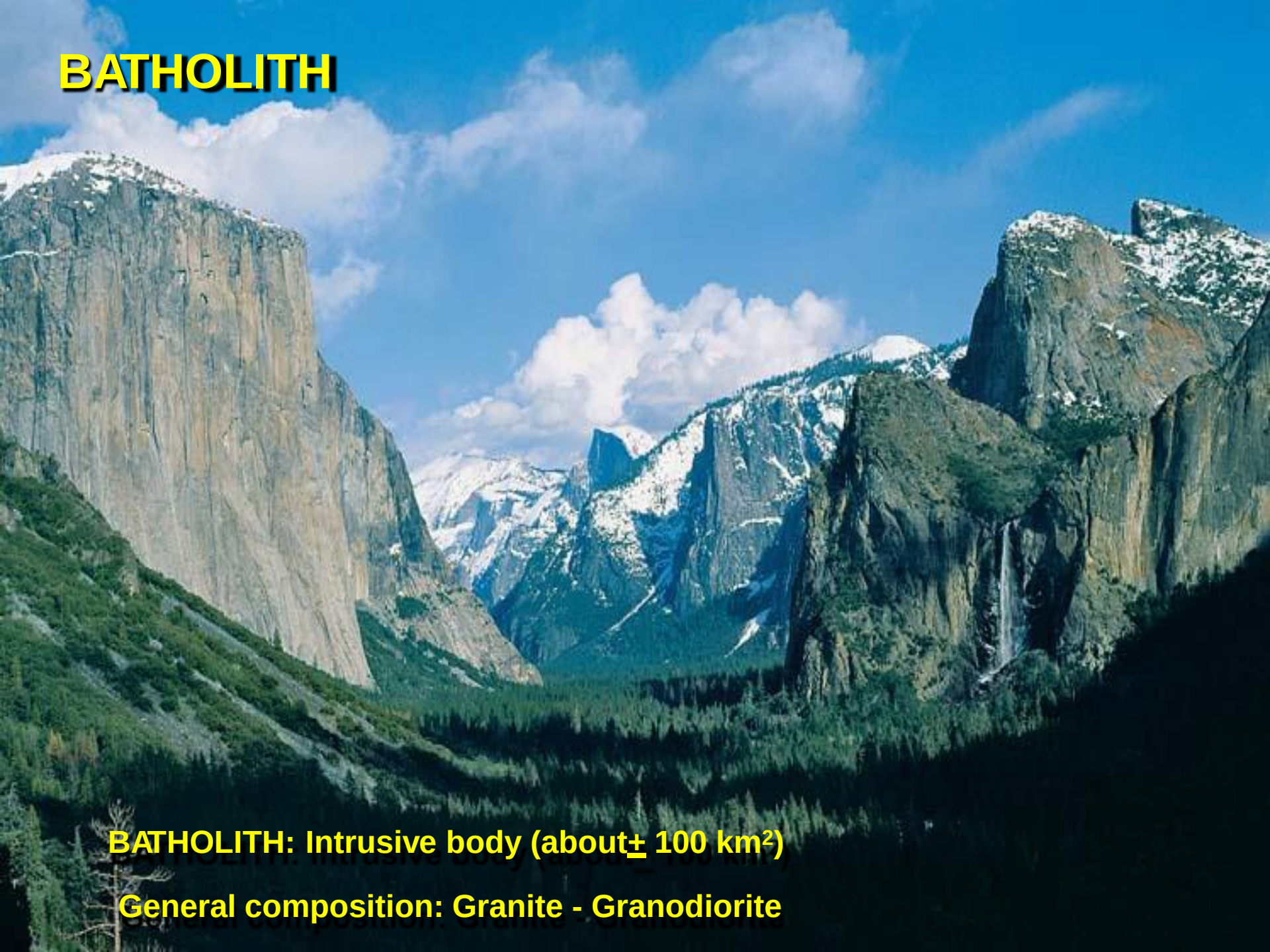

DIKE (DISCORDANT)
ROCK STRUCTURES
DIKE


SILL (CONCORDANT)
ROCK STRUCTURES
SILL

VOLCANIC NECK (PLUG)

Volcanic Neck: Volcanic plug/crater remnant in the surface

BATHOLITH



BATHOLITH: Intrusive body (about ± 100 km²)

General composition: Granite - Granodiorite

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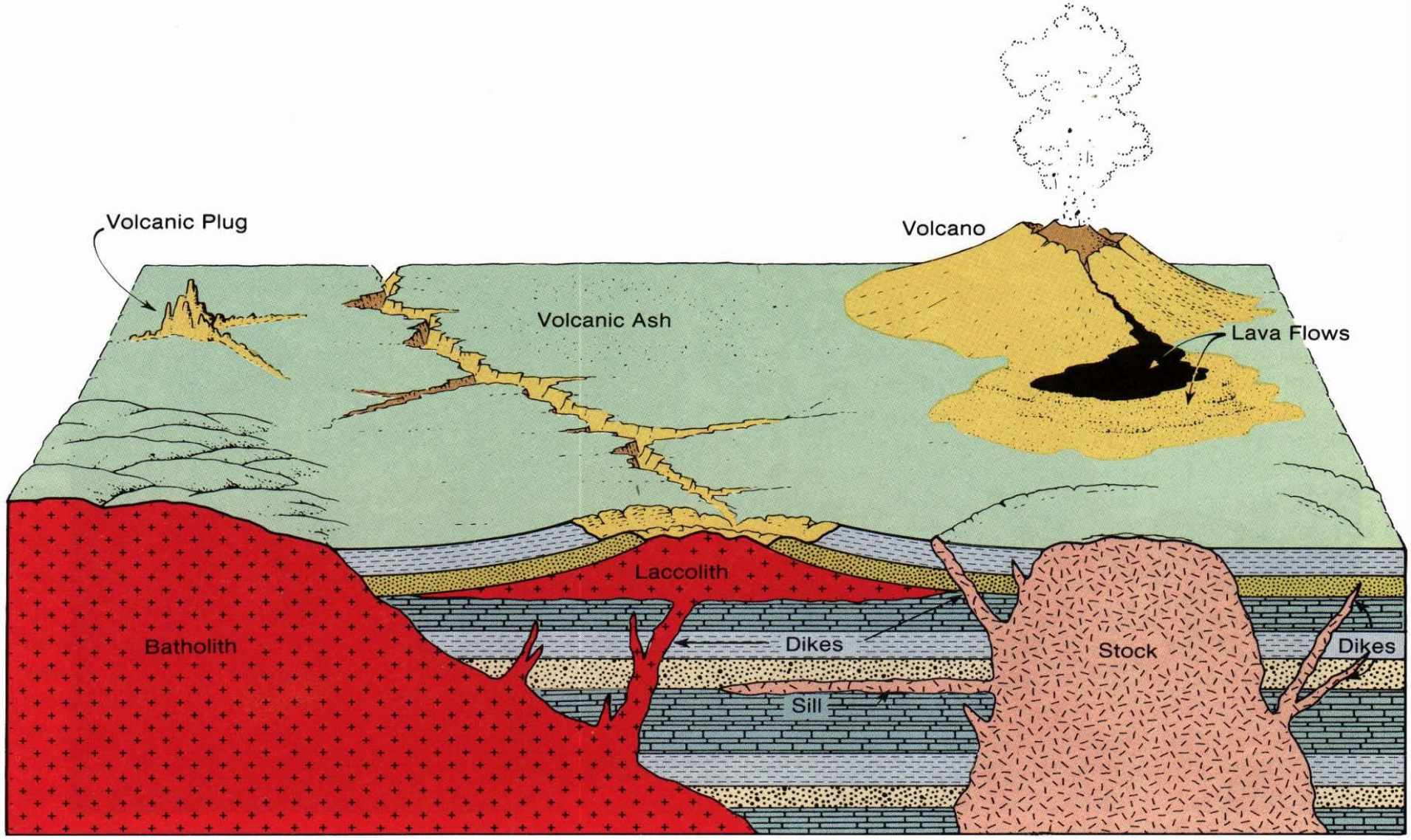
Igneous Rocks

Igneous Body



Block diagram showing various modes of occurrence of igneous rocks.